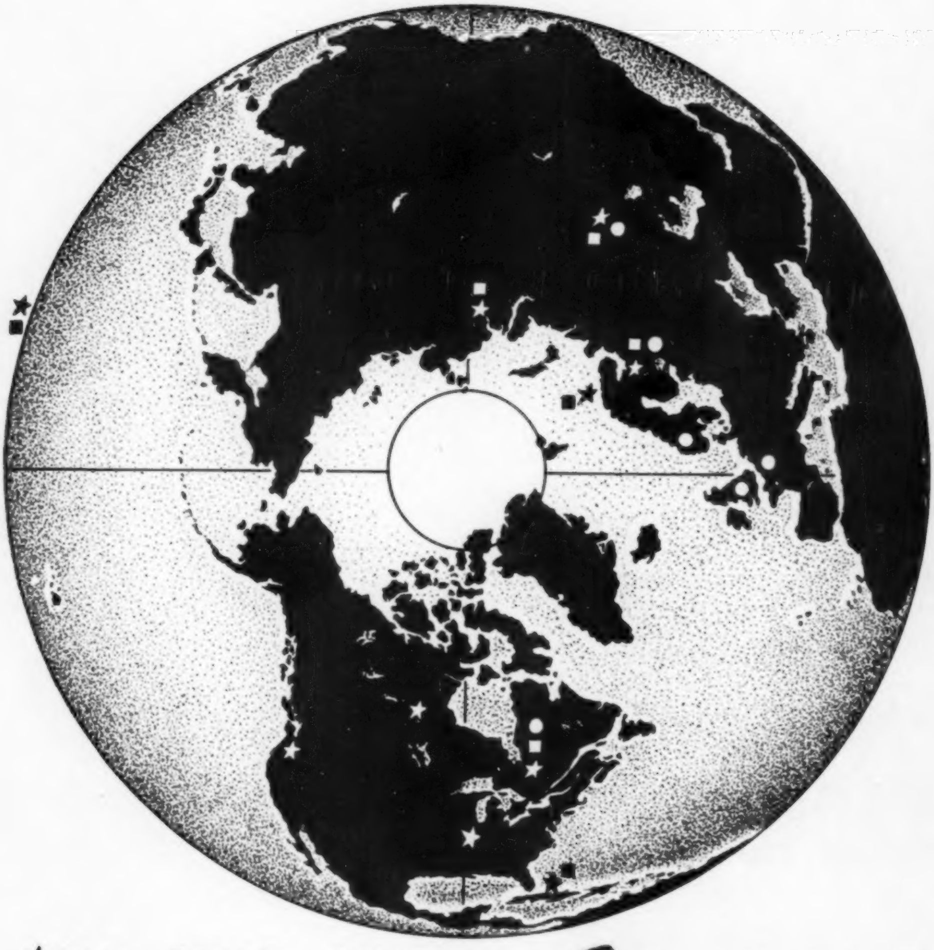
MINING ENGINEERING

AUGUST 1951



★ Ore bodies ■ Mills, smelters ● Refineries

Nickel

See Page 664

MINING ENGINEERING

Incorporating Mining and Metallurgy, Mining Technology and Coal Technology
VOL. 3 NO. 8 AUGUST, 1951

The AIME publishes: Mining Engineering, Journal of Metals, Journal of Petroleum Technology

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $9 foreign; $6 for AIME members, or $4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies $.75; special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publication. Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC.

FEATURES

Reporter ... 661
Editorial: Painting Screens ... 663
Trends ... 658
AIME News ... 713
Drift of Things ... 724
Coming Events ... 730
Manufacturers' News ... 654
Meet the Authors ... 651
Letters to the Editor ... 642
Book Review ... 678

ARTICLES

NICKEL: Third in a Series on Strategic Minerals ... 664
Enrollment Study Shows Decrease in Future Engineers ... 674
Open-Pit Forum—Truck Haulage at Inspiration ... 679
Linatex ... 680

TRANSACTIONS

Metallurgical Applications of the DorrClone ... 681
Comparative Results with Galena and Ferrosilicon at Mascot ... 691
Cyclone Thickeners, A Practical Solution for Closed Water Circuit Operation ... 699
Acid Drainage from Coal Mines ... 703
The History and Development of Phosphate Rock Mining 708

Personnel Service 647
Professional Services 734
Advertisers Index 736

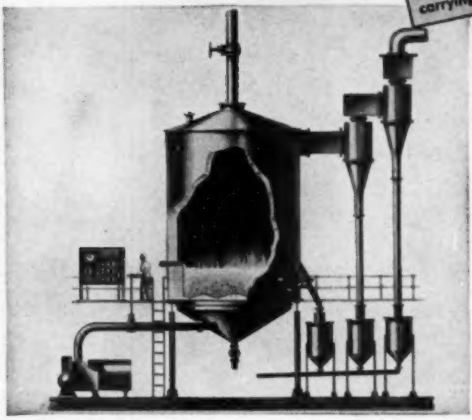
COVER: The nickel mines and producing facilities of the world are shown on the globe pictured on the front cover. All of these operations with the exception of New Caledonia (outside the hemisphere) and Cuba are within the range of Russian based bombers. Lynn Lake, Manitoba; Cuba; Douglas County, Ore.; and Fredericktown, Mo., are not producing nickel yet but are prospective sources. The complete story of the world resources, production, uses, defense impact, and outlook for nickel are told in the article beginning on page 664.

Can you use

14-15% SO_2 GAS from PYRITE

Dorrco FluoSolids* will produce it . . . at lower investment and operating costs than conventional roasters.

FACTS ON SO_2 PRODUCTION BY FLUOSOLIDS



GAS STRENGTH will average 14-15% SO_2 dry basis from pyrite carrying 48-50% sulphur.

GAS CLEANING EQUIPMENT is smaller because of smaller gas volumes.

FEED can be relatively coarse . . . flotation concentrate to 35 mesh—jig or table concentrate to 14 mesh.

MINIMUM MAINTENANCE . . . no moving parts exposed to high temperature — long refractory life.

NO SCALING . . . temperature accurately controlled below fusion point.

NO EXTRANEOUS FUEL is needed once fluidized bed is up to calcining temperature.

PROCESS SHUT-DOWNS of two or three days present no roasting problem.

COMPLETE INSTRUMENTATION eliminates the personal factor in operation.

● Sulphuric acid manufacturers and all users of sulphur dioxide faced with a shortage of elemental sulphur will find in FluoSolids an economically feasible means of tapping sulphides as an alternate source of SO_2. Utilizing the principle of fluidization, The Dorrco FluoSolids System is a distinct departure from conventional roasters. It brings SO_2 production from those sources down to a reasonable investment and operating cost level.

Its economy, simplicity and ease of operation are indicated by the facts above. For more detailed information write to The Dorr Company, Stamford, Conn., or in Canada, The Dorr Company, 80 Richmond Street West, Toronto 1.

*FluoSolids is a trademark of The Dorr Company, Reg. U. S. Pat. Off.

DORRCO

DORR

WORLD - WIDE RESEARCH · ENGINEERING · EQUIPMENT

THE DORR COMPANY · ENGINEERS · STAMFORD, CONN.
Associated Companies and Representatives in the principal cities of the world

Look Into this Traylor TC Gyratory for efficient, large volume, primary crushing

NEARLY 12 FEET across the *non-weaving, straight line bar type spider* of this 60 inch Traylor TC! Six smaller sizes, down to 20 inch, are proportionately just as rugged . . . have feed openings of the same generous proportions.

YES, THAT'S THE FAMOUS, exclusive Traylor BELL HEAD and CURVED CONCAVES combination that nips larger rock . . . crushes it more uniformly . . . saves power, time and maintenance expense.

UPPER AND LOWER SHELLS are kept as simple as possible. Transportation and installation problems control the number of sections of each. The Traylor method of assembly assures single casting rigidity.

THE *one* crusher which brings *all* of the advantages of gyratory crushing to primary operations is the Traylor TC Gyratory. In it *alone* are found the Traylor *bell head* and *curved concaves* which have become the by-word of gyratory crushing performance and economy. Eccentric and counter shaft bearings are protected from excessive wear by the simple, effective Traylor dust seal and a water-cooled, forced-flow oil lubricating system. If you need a large volume primary crusher to satisfy rising production demands, it will pay you to investigate a Traylor TC Gyratory today.

MAIL THIS COUPON
to get full details on a Traylor TC Gyratory

TRAYLOR ENGINEERING & MANUFACTURING CO.
375 MILL ST., ALLENTOWN, PA.

I would like to see how a Traylor TC Gyratory can increase the efficiency of my plant.

Name ____________________

Company ____________________

Address ____________________

____

SALES OFFICES: New York, N.Y.; Chicago, Ill., Los Angeles, Calif.
Canadian Mfrs: Canadian Vickers, Ltd. Montreal, P.Q.

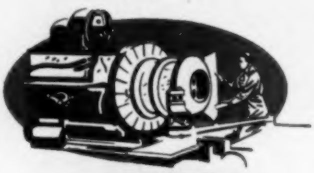
A "TRAYLOR" LEADS TO GREATER PROFITS

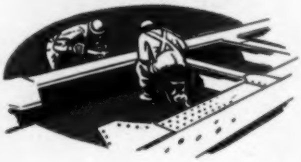
Traylor

Rotary Kilns, Coolers and Dryers · Grinding Mills
Jaw, Reduction and Gyratory Crushers · Crushing Rolls

"It ain't the individual nor the army as a whole
But the everlastin' teamwork of every bloomin' soul."

Excerpt from "Cooperation"
by J. Mason Knox





When a contract is awarded to Heyl & Patterson for Heavy Bulk Materials Handling Equipment every member of the H & P organization "Gets Into the Act."

Heyl & Patterson's ability to do the WHOLE JOB, *with their own forces,* All The Way from Design to Erection until the apparatus is performing satisfactorily, has earned the respect and confidence of our customers in the Mining, Steel, Power, Railroad and Aluminum industries.

Heyl & Patterson can guarantee "*CONTROLLED QUALITY*" because we have *OUR OWN* Engineering Department, *OUR OWN* Fabricating Plant and *OUR OWN* Erection Department.

Since 1887 the economic value of H & P "*CONTROLLED QUALITY*" has been demonstrated by the performance records of Heavy Bulk Materials Handling Equipment, designed, fabricated and erected by Heyl & Patterson.

Every *NEW* Contract is a *NEW* Challenge not only to H & P Engineers but to every person in our fabricating Plant and in our Erection Department.

The *WHOLE JOB HAS TO BE RIGHT.* This is the H & P Policy that governs every step of the way from the first consultation with a customer until the *WHOLE JOB IS IN SUCCESSFUL OPERATION.*

Ore Bridges
Railroad Car Dumpers
High Lift-Turnover-Rotary
Coal Preparation Plants
Coal & Coke Handling Equipment

Boat Loaders and Unloaders
Rotary Mine Car Dumpers
Coal Crushers
Coal Storage Bridges
Car Hauls and Boat Movers

Bradford Breakers
Refuse Disposal Cars
Thorsten Coal Sampling Systems
Kinney Car Unloaders

Pig Iron Casting Machines
Cyclone Thickeners
Thermal Dryers
The Drying Dutchman
Reineveld Centrifugal Dryer

Heyl + Patterson, Inc.
"SINCE 1887"
55 WATER STREET · PITTSBURGH 22, PA.

Heavy Bulk Materials Handling Equipment
All The Way from Design to Erection

Letters to The Editor

Probable, But Not True

"I feel that as a loyal Cleveland-Cliffs man I must 'call' you on your remark: 'Today it is probable that the Pyne Mine produces the greatest tonnage through a single shaft of any iron mine in the United States.' (*ME, December 1950, P. 1231*).

"I am glad you used the word 'probable' . . . . Starting in 1948 our Mather mine A shaft produced slightly over one million tons. In 1949 this production was again increased . . . . In 1950 A shaft alone produced 1,251,963 tons and shipped 1,274,440 . . . . As far as we can find out, last year's production at Mather A was the largest production ever obtained through a single shaft in any iron mine in the entire world.

F. J. Haller
Manager Michigan Mines
Cleveland-Cliffs Iron Co.

• *"Probable" is every editor's secret weapon, and sometimes covers a multitude of sins. We're happy to present the facts in this case, and are grateful to Mr. Haller for offering them.*

The Value of Publicity

"A little over a year ago I sent you a photograph of an old miner's lamp and requested that it be published in MINING ENGINEERING together with a statement . . . asking for information as to its probable origin.

. . . I have received quite a number of letters and developed some interesting correspondence with mining men in different parts of the world. I got the information I needed . . . and it may be possible that I will get some additional lamps for my collection. Replies were received from the following places: Beverly Hills, Calif.; Salt Lake City, Utah; Hollywood, Fla.; Ottawa, Ont., Canada; London, England; The Hague, Netherlands; Rupprechtstegen, Germany; Westfalen, Germany; and Namaqualand, South Africa."

Victor H. Verity
Attorney at Law and
Mining Engineer
Tucson, Ariz.

Yes, More Research

"I was greatly intrigued by your excellent editorial entitled, "Let's Do Our Own Research" in the May issue of MINING ENGINEERING. Most leaders in the mining industry have in the past based their thinking on immediate, and very often false premises, and consequently committed the mining industry to a stereotyped existence. It has been said the greatest hindrance to the mining industry is the inability of management to accept innovations.

"Let us fervently hope that your editorial will plant seeds of new thought among the mining fraternity which, amid cries of heresy, may yet grow to fruitful maturity."

Harold B. Ewoldt
Boston, Mass.

Brent N. Rickard

"I was very sorry to note, in your May issue, the death of Mr. Brent N. Rickard. This fine man has helped a great many of us along the way of life.

"I know I speak for a good number of us in expressing deep regret at the passing of this fine gentleman. Whether in arctic cabin or altiplano, where, as far as I know, Brent had never been, or talking with his friends, the Arizona prospectors, one had only to see faces light up at the mention of his name, to know the caliber of the man.

"Along with others, at the time, I was experiencing difficulty remaining in college without a job. After carefully noting the name of the manager, Brent N. Rickard, I made a trip to the El Paso Smelter. As Mr. Rickard was out in the plant I told my story to the employment agent and went on to other prospects. Several days later, upon returning from classes I saw that there was a stranger sitting in our porch swing, talking with my father. As I climbed the steps he arose with a smile, extended his hand saying, 'I'm Brent Rickard and I understand you're looking for a job.' I must admit that I had seen few managers, in my search for a job, and in my wildest dreams I would not have pictured one coming to see me. Yet there he was kindly asking about my studies and the necessity for my working. After assessing the situation Brent pointed out that one should have some time for study and that there were others equally in need of work so that if I would like to work every other night in conjunction with another student, he would be glad to have me work for him.

"This was neither a whim of Brent's nor a patronizing gesture and somehow, standing there looking at him, I knew that he was not only welcoming me into the mining fraternity with dignity but placing upon me a responsibility for proving I belonged there.

"Years went by and infrequently our paths would cross. Each time I resolved to find words which, in some way, would show my appreciation for that intangible something, beyond mere physical help, which Brent had given me. Each time in some subtle, disarming way this unusually fine man would not allow me the opportunity.

"Now, with Brent gone, I, along with a good many others scattered over the globe, have a deeper understanding of the debt we owe him and the only way he would have it cancelled."

Wendell T. Brown
Compañia American Smelting
Santiago de Chile

NEEDS ONLY ONE KIND OF LUBRICANT!

another good reason for choosing

THE GARDNER-DENVER VP4 Sump Pump

You don't grease a Gardner-Denver VP4 Sump Pump. Only a *single* kind of lubricant is required. One filling of oil lubricates every moving part — lasts for 24 operating hours — saves your greaser's time — minimizes the chances for lubrication neglect.

The VP4 solves other "Mud Puddle" problems for you, too —

Gardner-Denver VP4 Sump Pump dewatering a tunnel under construction.

It won't bury itself in a muddy sump . . . can't suck grit and water into the motor or bearings. An automatic governor idles pump when suction runs dry — saves air and wear. Easy to handle . . . compact, lightweight.

For complete specifications, write today for Bulletin VP4.

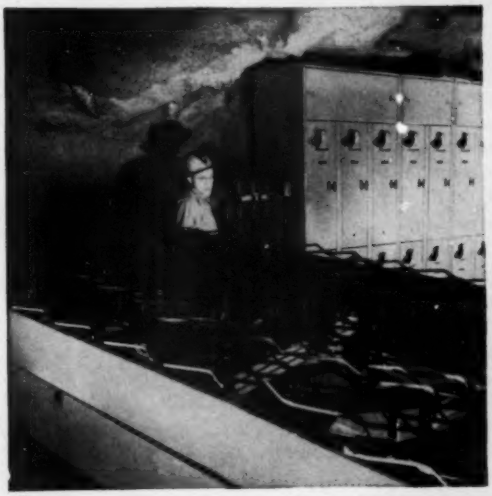
SINCE 1859

GARDNER-DENVER

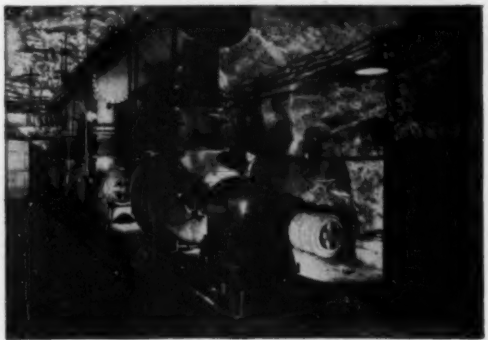
Gardner-Denver Company, Quincy, Illinois

In Canada: Gardner-Denver Company (Canada), Ltd., Toronto, Ontario

Co-ordinated G-E drives and distribution equipment help maintain continuity of production at New Jersey Zinc's unique Gilman, Colo. concentrating plant



3 Grouped motor control is provided at several points throughout the mill by compact G-E Cabinetrol* units. Space-saving Cabinetrol "packages" include all controls and instruments needed for various milling processes. This neat assembly, together with its associated push-button stations, is located in the mill's flotation cell room.



4 After grinding the ore, lead minerals are separated from zinc minerals and waste, and then zinc minerals are separated from waste tailings in flotation cells. Air for flotation cells is supplied by these blowers, driven by three 125-hp 440-volt G-E a-c motors, with G-E control at right.

*Reg. trade mark of General Electric Co. for enclosed control panel equipment.

5 Power for the mine comes down from the surface at 13,800 volts through 4500 feet of G-E armored cable. At this substation—comprising a G-E switchboard and three 150-kva Pyranol† transformers with gas absorbers—it is stepped down to 440 volts for utilization throughout the mine's two lowest levels.

6 To protect equipment against damage from excessive overcurrents caused by heavy overloads or short circuits, the mill uses four G-E 3-pole air circuit breakers rated 600 amperes, 600 volts. G-E air-circuit breakers, selected for adequate interrupting capacity, help safeguard against loss of production in all milling operations.

GE

CO-ORDINATED EQUIPMENT

for the Mining Industry

At every stage in ore processing—mining, concentrating, smelting, or refining—a G-E mining industry specialist can help you solve your electrical problems efficiently, economically. He's a good man to know. Call him soon! *General Electric Company, Schenectady 5, N. Y.*

†Registered trade mark of General Electric Co. for askarel.

Personnel Service

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York Office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Geologist, 30, married, M.A. degree geology. Two years' experience Mexico and Philippines as mining geologist. Expert handling of men. Available immediately. Foreign location preferred. M-633-514-E-4, San Francisco.

General Manager, now available. Aggressive, have outstanding record in management of many engineers and men working on the design, construction and operation of big industrial projects and coal mining properties requiring managerial and engineering ability of the highest type. Wire for interview. M-634.

Mining Geologist, 27, single. Two years assistant mine engineer shrinkage stope iron mine. Knowledge Spanish and German. Desire position as mining geologist or assistant engineer in open pit or underground metal mine. Foreign service preferred, any location considered. Presently employed. M-635.

POSITIONS OPEN

Mining Engineer capable of making base maps of various mine levels from various survey records. Should be able to draw primary coordinates and plot the coordinates of the various stations on the map. Following this, engineering work in connection with the construction work for expansion of mill. The work then could develop into underground surveying and possibly underground supervisory position as shift boss. Will consider recent graduate. Single status. Salary open. Location, South. Y5690.

Metallurgical Engineer, 22-35, B.S. degree, for special investigation and development work in precision manufacturing operations. Previous experience in metallurgical processing or design of precision machinery helpful but not required. Location, suburban Philadelphia, Penna. Y5680.

Metal Mining Engineers willing to work in various countries for periods of time ranging from 5 months to 2 years. (a) Engineers with good training in layout and equipment of open pit copper mines. (b) Engineers experienced in underground mining of narrow veins. (c) Engineers experienced in the mining of iron and manganese open pit deposits. (d) Engineers with experience in the mining of nonmetallics. Short term engagements will be on a per diem, plus expenses basis and long term engagements will be on liberal salary, subsistence allowances, plus travel expenses. Headquarters, Pennsylvania. Y5667.

Personnel Service

(Continued from page 647)

Mine Master Mechanic and Chief Electrician with responsible experience in mechanized coal mining, to supervise installation and maintenance of underground mechanical and electrical equipment of large, highly mechanized potash operation. Salary open. Location, Southwest. Y5664(a)

Mining Engineer, young, single, or with wife only, for the supervision of a diamond drilling job in Jamaica, B.W.I. Position temporary, with possibility of becoming permanent if property is proven by the drilling. Salary, $5400 a year plus traveling expenses. Living conditions ideal. Y5611.

Engineers. (a) Superintendent for ore storage drying and grinding departments. Should have considerable operating experience in handling personnel and equipment of a large concentration mill, handling large amounts of ore, i.e., 5,000 tons/day. (b) Superintendent for an ammonia recovery plant, experienced in an oil refinery, by-product coke oven plant or large chemical plant involving distillation and/or similar processes. Salaries, $4800-$7200 a year. Location, Cuba. Y5602.

Mining Engineers. (a) Placer Development Engineer, 40-45, experienced in operation of dragline gold dredges, hydraulicking, sluicing, underground gravel mining, high list pumping diesel and steam, etc., to function as resident engineer at large placer gold mine. Salary, $7000 a year in U.S. currency, tax exempt. Three year contract. (b) Mining Engineers, 3, 30-40, experienced in exploration and examination of placer goldfields for work in placer goldfields. Salary, U.S. $4800 a year in U.S. currency, tax exempt, quarters and living allowance. Two year contract. Temperate climate. Location, Ethiopia. Y5574.

Metallurgical Engineer with several years' experience in ore concentration. Work to be mill operation and some development. Expanding organization. Salary, to $6000 a year. Location, Southeast. Y5405.

Chief Geologist, Assistant Geologists and Geophysicists for bringing into production new properties in Bolivia. Will examine prospects and attempt to find completely new mines. In addition to tin and base metals, attention will be paid to nonmetallics as well as minerals not generally recognized by average prospectors. Salary open. Y5384.

Mining Engineer, 30-40, with three to five years' mining experience, preferably in mica, and also with some knowledge of flotation and purification processes. Salary open. Location, Ohio. Y5362.

Superintendent to take charge of a mine and mill at copper, silver and gold property. Salary open. Location, Montana. Y4975.

Junior Mine Engineer, recent college graduate, competent underground surveyor and draftsman. Standard three-year contract, single, free transportation furnished by air, four weeks vacation yearly plus free living quarters. Salary, $3300 a year plus yearly bonus. Location, Bolivia. Y4872.

MINING EXECUTIVE AND ADMINISTRATOR

with full experience in the operation of large low-grade gold and base metal mines seeks a change of position. All replies treated confidentially. Answer

Box G-14 MINING ENGINEERING

MAINTENANCE ENGINEER

Copper Refinery: New copper smelter in Northeastern Turkey. Must be familiar with coal fired reverberatory furnaces and horizontal converters. Good living conditions and excellent climate.

Box G-15 MINING ENGINEERING

COPPER SMELTER SUPERINTENDENT

For new copper smelter in Northeastern Turkey. Must be familiar with coal fired reverberatory furnaces and horizontal converters. Good living conditions and excellent climate.

Box G-16 MINING ENGINEERING

Experienced mining engineer wanted to supervise Indian manganese mines operated by Indo-American concern. Terms open for discussion.

Box G-17 MINING ENGINEERING

MINING AND ENGINEERING TECHNICAL SERVICE

Mineralogist with minimum of 2 years' experience in concentration of minerals. Basic chemistry studies desirable.
This is a real opportunity to gain experience in technical service and field development work with a rapidly expanding chemical division of one of America's foremost companies.
Send resume and salary expected to **Manager of Sales Development, Armour Chemical Division, 1355 West 31st Street, Chicago, Illinois.**

For the Optimum Recovery of these Strategic Minerals

- ★ ANTIMONY
- ★ CHROMITE
- ★ COBALT
- ★ DIAMONDS
- ★ FLUORSPAR
- ★ MANGANESE
- ★ MOLYBDENUM
- ★ SULPHUR
- ★ TIN
- ★ TUNGSTEN

Strategic Minerals

Government Launches $500 Million Program To Up U. S. Output

Tripled Tungsten Production, Twic[illegible] Much Antimony A[illegible]ong the Goals

Timely and Helpful Benefici[illegible] Data Compiled by the Cyanamid Mine[illegible]ressing Laboratory

Essential to the success of th[illegible]r increasing the output of strategic minerals is the development[illegible] concentration methods. No prospect can be realistically evaluat[illegible]milling costs are known. For known but unworked deposits, efficie[illegible]ciation is frequently the key to prompt and successful commercial dev[illegible]ent. In fact, profitable metallurgical processes are the foundation [illegible]h all plans to expand strategic mineral production ultimately depend[illegible]

As our constructive [illegible]bution to [illegible] many metallic and non-metallic minerals, Cya[illegible] current practice and avenues of approach to the benefic[illegible] needed minerals. In conjunction with other available published data [illegible] Cyanamid Mineral Dressing Laboratory, these special technical bulletins represent practical guideposts to progress in solving the mineral dressing problems of the expansion program. They are offered, without cost or obligation, as a preliminary to confidential discussion of your particular problems with Cyanamid Field Engineers.

Only Carlon...

the first real pipe that is plastic!

Completely resistant to the chemical action of surphurous waters, alkalies, metallic salts, and other corrosive wastes, CARLON solves piping problems in surface and subsurface mining operations. This durable new pipe is **guaranteed** against rot, rust, and electrolytic corrosion, and it has a service life many times longer than ordinary pipe.

Lightweight CARLON plastic pipe does not require materials handling equipment or special tools for rapid installation. Recommended applications for this pipe are drinking water and drainage systems, ventilating lines, hydraulic sluicing, intake and exhaust piping, dredge discharge lines, low-pressure air lines, etc.

Both flexible and rigid types of CARLON are available in standard pipe sizes. Flexible pipe is furnished in long lengths which conform to irregular surface contours or ditch lines and require fewer fittings per installation. Rigid CARLON is shipped in threaded and coupled random 21-foot lengths which can be joined quickly by means of threaded plastic fittings. To meet individual job requirements, rigid CARLON can be cut to desired lengths and threaded with standard pipe dies.

Specify ONLY CARLON to obtain the most versatile mine pipe available today.

> At present, raw material shortages are limiting the production of certain types of CARLON pipe. Every effort is being made, however, to overcome this problem and to meet the demand and need for CARLON . . . the first real pipe that is plastic!

CARLON CP

156-CP

CARLON PRODUCTS CORPORATION

IN CANADA: MICRO PLASTICS, LTD., ACTON, ONTARIO

10348 MEECH AVENUE • CLEVELAND 3, OHIO

Meet The Authors

R. B. FULLER

D. B. GROVE

S. A. BRALEY

R. B. Fuller *(The History and Development of Phosphate Rock Mining, P. 708)* has been manager of International Minerals and Chemical Corp.'s Florida phosphate division since 1926. A South Carolinian by birth, Mr. Fuller attended the College of Charleston, and later the University of Florida, studying civil engineering. Managing one of Florida's largest industries, Mr. Fuller is also a member of a host of other organizations and civic groups. He is active in Kiwanis, the Boy Scouts, the State Chamber of Commerce, the American Mining Congress, and the National Citizens Committee for the Reorganization of the Executive Branch of the Government. Mr. Fuller is also an AIME member.

T. Bilson *(Truck Haulage Improved at Inspiration by Attention to Details, P. 679)* has been with Inspiration Consolidated Copper since 1937, as engineering clerk, asst. contract engineer, underground shift foreman, open-pit shaft foreman, and is now pit foreman. Operation and maintenance of off-the-highway trucks is a subject of particular interest to him. Aside from his duties at Inspiration, he enjoys photography, fishing, and collecting mineral specimens. AIME member Bilson was born in Michigan, went to high school in Globe, Ariz., and attended the University of Arizona.

D. B. Grove *(Comparative Results with Galena and Ferrosilicon at Mascot, P. 691)*, is known as the "East Tennessee Hillbilly Mill Man" to his associates. He was born in that state, attended the University of Tennessee, and went to work for American Zinc at Mascot, where he's been ever since. In 1926 he took over as mill superintendent for the operation.

S. A. Braley *(Acid Drainage From Coal Mines, P. 703)* took his Ph. D. from the University of Illinois in 1917 and remained to teach at his alma mater for 10 years. Then, in 1927, he joined the Mellon Institute in Pittsburgh, doing research on steel until 1946, at which time he took over his present assignments on mine acid control. Dr. Braley is a member of ASTM and ACS.

J. H. Polhemus *(Comparative Results with Galena and Ferrosilicon at Mascot, P. 691)*, a metallurgist with American Zinc of Tennessee since 1946, first joined that company in 1943, as a sample foreman. The Navy called him in 1944, and he spent two years at mine disposal work as a lieutenant, j.g. before returning to the company at Mascot, Tenn. Mr. Polhemus, a New Jerseyite by birth, attended Admiral Farragut Naval Academy and the Missouri School of Mines. He's an AIME member, and also belongs to the Holland Society of N. Y. and the Tennessee Archaelogical Society. Archaelogy, fishing, chess and philately occupy his leisure hours.

Authors

R. B. Brackin (co-author with Mr. Polhemus), assistant mill superintendent at American Zinc since 1946, was also mill superintendent at the Waite Amulet mines in Quebec for 6 years prior to joining the Mascot operation. He has also done underground work at the Delnite mines, in Ontario, and at Noranda in Quebec. Mr. Brackin was born in Ontario, attended Chatham Collegiate Institute and the University of Toronto, from which he graduated (with honors) in 1940 with a B.Sc. He's a member of both AIME and CIMM. His hobbies include golf and mountain climbing.

J. P. Blair *(Cyclone Thickeners, A Practical Solution for Closed Water Circuit Operation, P. 699)* took his B.S. in civil engineering from the University of Pittsburgh in 1948, spent a year with Roberts & Schaefer as a field engineer, and has been a coal preparation engineer with Heyl & Patterson since 1949. Mr. Blair is an AIME member, and is currently a member of the Fine Coal Cleaning Committee. He is also a Tau Kappa Epsilon brother, and a junior member of ASCE.

W. B. Plank *(Engineering Enrollments Survey, P. 674)* has been teaching at Lafayette College, Easton, Pa., since 1920, holding the John Markle Professorship and being head of the department of mining and metallurgy. He was graduated from Pennsylvania State College in 1908 with degrees in mining but returned the following year for a masters in metallurgy. Professor Plank has been preparing and submitting for publication by AIME the enrollment studies like the one in this issue biennially since 1933. He is an active participant in the affairs of the Mineral Industry Education Division of AIME and also in the American Society of Engineering Education. He and Mrs. Plank have traveled through most of the mining areas of the United States.

H. J. Petrie *(co-author with Professor Plank)* took his Bachelor of Science degree in mining at Columbia School of Mines graduating in 1944. He did his war service in the United States Navy acting as assistant public works officer in the military government of Guam. Returning to the States he re-entered Columbia to take his Master's degree. He recently left Worthington Pump Co. to become an instructor in mining at Lafayette.

Manufacturers News

Chain Belt Offers Self-Priming Pumps

A new line of self-priming centrifugal pumps, ranging in size from the 1½ in. model 4M to the 6 in. model 90M, has been announced by the Chain Belt Co. of Milwaukee. Capacities range from 4000 to 90,000 gal per hr.

Features claimed by the manufacturer include: easy and inexpensive replacement of wearing parts, patented high carbon steel air peeler, and an impeller shaft seal that is never subjected to pumping pressure. Detailed literature on this product is available. **Circle No. 1**

Vibrolator

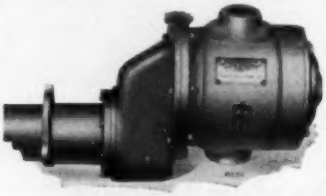
The Vibrolator is used to aid the movement of such materials as coal, granular chemicals, cement and other materials that arch and resist movement toward the outlet of hoppers and bins, or where wet mixtures tend to entrain air. It vibrates the storage bin and causes materials to flow steadily toward the outlet. The powerful all-directional vibration does not damage the hopper or storage bin, according to the manufacturer. The Vibrolator can be mounted in many different ways and comes in different sizes to allow for variances in operating conditions, materials, and equipment. It is said to be noiseless in operation, self-lubricating and starts instantly without manual assistance. This product is manufactured by *Martin Engineering Co.* **Circle No. 2**

Air-Washing Coal

The *Roberts & Shafer Co.* have recently announced improvements in their machine for air-washing coal. The coal and refuse particles entering at the upper or feed end are stratified by means of pulsating air. After the layer or refuse is formed it travels forward into pockets or wells from which it is withdrawn. The upper layer of coal continues to travel over the slowly moving bed of refuse and is removed at the opposite end. Dust created by the pulsating air is sucked into an overhead hood, and is recovered in a filter or cyclone dust collector. For fine coal the deck is longer and there are four refuse draws, normally the products of the first two draws are discarded as refuse and the third and fourth draws are middlings. For coarse coal the deck is shorter and there are only two refuse draws, one for refuse and one for middlings. Some of the improvements claimed for this machine are: Less air volume is required for stratification because of the oscillation which assists the movement of material along the deck, and the zoning plate is eliminated since the shaking deck adequately maintains a uniform bed. **Circle No. 3**

Air Starting Motors for Gas, Diesel, Engines

Ingersoll-Rand is now offering two new air starting motors for cranking diesel and gasoline engines with piston displacements up to more than 3500 cu in. Although normally operated by compressed air, they are also suitable for operation on natural gas at sufficient pressure. These air starters



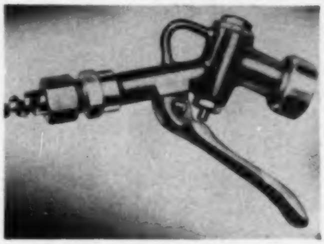
eliminate the necessity for generators, storage batteries, and battery maintenance and replacement. The air motor consists of a hardened steel rotor with five vanes, revolving in an alloy cylinder, and enclosed by bronze end plates. These starters are available in the 9BM size, which develops up to 16 hp and requires 7 cu ft of air per start; and the size 20BM, which develops up to 41 hp and requires about 16 cu ft of air per start. The smaller starter weighs 40 lb, and the larger model 103 lb. **Circle No. 4**

Radial Drilling Machine

A compact radial drilling machine is claimed to reduce fatigue and keep idle time to a minimum. It has an all-electric drive with one motor providing drilling, and one motor for elevating power. Both motors are controlled by single stick-type switch on saddle operated through a contactor panel built in the rear of arm. All driving gears are made from chrome-nickel steel, heat treated to 100 tons and ground on the teeth; shafts are of high carbon heat-treated steel and all run in ball bearings. Sliding gears are mounted on 6 spline shafts. The lubrication of the saddle gears is achieved by a built-in pump. Electricity is supplied to NEMA standards, 220 v 3 phase 60 cycle. This machine is manufactured by *Midgley & Sutcliffe* of Leeds, England and is distributed through British Industries Corp. of New York City. **Circle No. 5**

Fire Fighting Weapon

A unique fog gun has been developed by *Bete Fog Nozzle Inc.*, which makes it possible for companies to convert ordinary garden hose into a



mobile inside fire fighting instrument. With the new gun-type nozzle, a tap pressure of 30 to 120 psi will produce an effective fog that will instantly blanket and extinguish small fires. This instrument can also be used for cooling machines and molds and can be used for washing materials like coal and gravel. Nozzles are available separately, or in a kit which includes adaptors for giving a spray range from the conventional hydraulic spray, through flat spraying, to unique mist spray. **Circle No. 6**

Two New Euclid Models

Two new rear-dump models of 22-ton capacity, with spring mounted axle drive, have been announced by the Euclid Road Machinery Co. The 45TD has a 286 hp Buda engine, and the 46TD is powered by a 300 hp Cummins engine. Both models have ten-speed transmission, and are available with standard or quarry body. Top speed with full payload is 32 mph. The double reduction planetary type drive axle is mounted on free-floating springs and is positioned to the frame by swivel-connected longitudinal radius rods. Movement in the spring brackets is thus permitted, and leaf breakage caused by twisting is thus avoided. An air-assist clutch, hydraulic booster steering, and an adjustable driver's seat are other features of these new models. **Circle No. 7**

Free Literature

(8) UTILITY TRUCK: New booklet issued by *Goodman Mfg. Co.* describes RHT-2 truck that delivers equipment directly to the point where it is to be used. The truck can be equipped with a cable reel or can be operated from a trailing cable entering through a junction box. The truck can be permanently electrically connected to a shortwall (direct or through a service switch), or arranged for disconnecting where it has other haulage duties to perform. Twenty-three combinations involving cable reel, wire rope reel, power take-offs, and service switch are possible. The controller is full magnetic, directional and provides a high and low tramming speed.

(9) DIAMOND CORE DRILLS: Bulletin # 71 available from *E. J. Longyear Co.* gives up-to-date specifications and operating data on Wolverine drills. These drills are exceptionally lightweight, which results in easy handling underground. The electric models are equipped with a clutch located between the motor and the three-speed transmission, permitting instant stopping of the drill without shutting down the motor. All models have a transmission which allows a selection of three drilling and three hoisting speeds.

(10) MINING EQUIPMENT: Catalog 551 on the MMP-JABCO line of improved equipment for more efficient mine operation has been published by *Mining Machine Parts, Inc.* Such products as clamp trolley tap, ground clamp, jaw clamp, fuseless taps, and plain hooks are illustrated and various operating characteristics described. A favorable feature of the jaw clamp is that it employs the use of a 3-positional eccentric cam action full hard brass clamp that grips the overhead grooved trolley wire. It is easily and quickly attached and allows for the cable to go up or down the heading or at a 90° angle to it.

(11) ROD MILLS: For fine crushing and grinding, *Hardinge Co., Inc.* has published a 12-page catalog. Bulletin #25-C contains a general discussion of the correct field of application of rod mills, for both wet and dry grinding. It covers methods of construction and design features of the Hardinge Conical, Flanged-End and Convex-Head rod mills, both trunnion overflow and peripheral discharge types. Specifications include sizes, weights, rod charges, speeds, horsepower ratings, types of liners, feeders, and other pertinent information.

(12) FAN-COOLED MOTORS: A new bulletin describes types of construction and ratings of *Allis-Chalmers Mfg. Co.* improved totally-enclosed, fan-cooled motors with tube-type, air-to-air heat exchangers. Included in the bulletin is a chart showing ratings of motors available in squirrel-cage, wound-rotor and synchronous types for both horizontal and vertical installation, and a cross-section view of horizontal motor construction features. Among these are capsule-type bearings, protected air intakes, and pipe-plug protected, tapped holes for checking air gap with feeler gages.

(13) CABLE-MOUNTINGS: Redesign of cable-control mountings for the new and larger line of bulldozers, gradebuilders, and root rippers is announced by the *Baker Mfg. Co.* in bulletin #895. The new cable models are for the A-C HD-9, HD-15 and HD-20 tractors. Redesign of the cable-control mounting provides maximum visibility, streamlined appearance, easy interchangeability, improved protection for cables and radiator and new push beam power tilt. The cable is located under the fender, close to the side of the tractor, well protected from brush and limbs. The built-in radiator guard with perforated grill, is an integral part of the cable frame. Quick, easy interchangeability between 'dozer, gradebuilder and root ripper is provided by removal of a bolt on each side, removal of wedges and detachment of the lower sheave block at the front.

(14) PRECISION SPEED CONTROL: Publication #1107 has just been released by the *Electric Machinery Mfg. Co.* which discusses precision speed control with the adjustable-speed magnetic drive. This 32-page book is technical in scope, and contains complete information both on the magnetic drive and the new magnetic amplifier Regutron speed control. The technical information is clarified through the use of many charts, diagrams, and illustrations.

(15) IMPACT BREAKER: A heavy duty impact breaker, called the PMCO Impact Master, has been developed by *Pettibone Mulliken Corp.* and is illustrated in their booklet #PMIM-1. The breaker features controlled impact action, an exclusive operating principle that controls the breaking operation and directs the flow of material through the machine to produce a highly uniform gradation cubical aggregate. Other features are extremely high ratio of reduction, low hp per ton of finished material, easy access to all parts, and large volume production with minimum plant investment. Rotors have three rigidly supported hammers each, and rotate on heat treated alloy steel shafts mounted on anti-friction bearings.

(16) ROLL BEARINGS: Complete range of standard sizes and characteristics of roll bearings for use with driven belt, or gravity conveyors is included in technical data bulletin #200 just released by *Arguto Oilless Bearing Co.* Impregnated with a specially formulated, non-oxidizing lubricant, the wood bearings are perpetually self-lubricating, unaffected by water or abrasives, require no maintenance, and will not drip. The roller tubing is faced to length and an Arguto bearing is press fit into both ends. The bearing flange has the same OD as the tubing and provides a shoulder against which the tubing is positioned.

(17) EARTHMOVING EQUIPMENT: This illustrated booklet features the new 6-cylinder supercharged DW 20 and DW 21 Diesel Engine. Easy working controls within convenient reach add to operating efficiency. A hydraulic ram is built into the steering gear and supplies power for the work of steering. Bulletin issued by *Caterpillar Tractor Co.*

Mining Engineering — **August**
29 West 39th St.
New York 18, N. Y.

Please send me { More Information ☐ / Free Literature ☐ / Price Data ☐ } on items indicated.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40

Name ______________________ Title ______________

Company ___________________________________

Street _____________________________________

City and Zone ______________________ State ______________

WANTED

More production with limited manpower

IT CAN BE DONE!

. . . with faster drilling CARSET JACKBITS

Because they are tipped with Carboloy inserts—one of the hardest metallic substances known to man—Carset Jackbits drill the hardest rock with a *speed* and *efficiency* which cannot be approached by the finest steel bits.

For instance, Carset Jackbits drill 50% faster—last from 50 to 400 times longer—practically eliminate bit changes and double the life of drill steel. They eliminate tapered holes saving up to 30% on dynamite—permit longer steels and feeds—require much less maintenance—and boost tonnage as much as 50% or more.

These advantages all add up to a tremendous increase in footage per shift—*without increasing your drilling crews.* Remember Ingersoll-Rand offers a complete line of equipment and service for rock drilling. Take advantage of our highly trained and skilled personnel. There is an Ingersoll-Rand branch office and distributor near you. Write or call today.

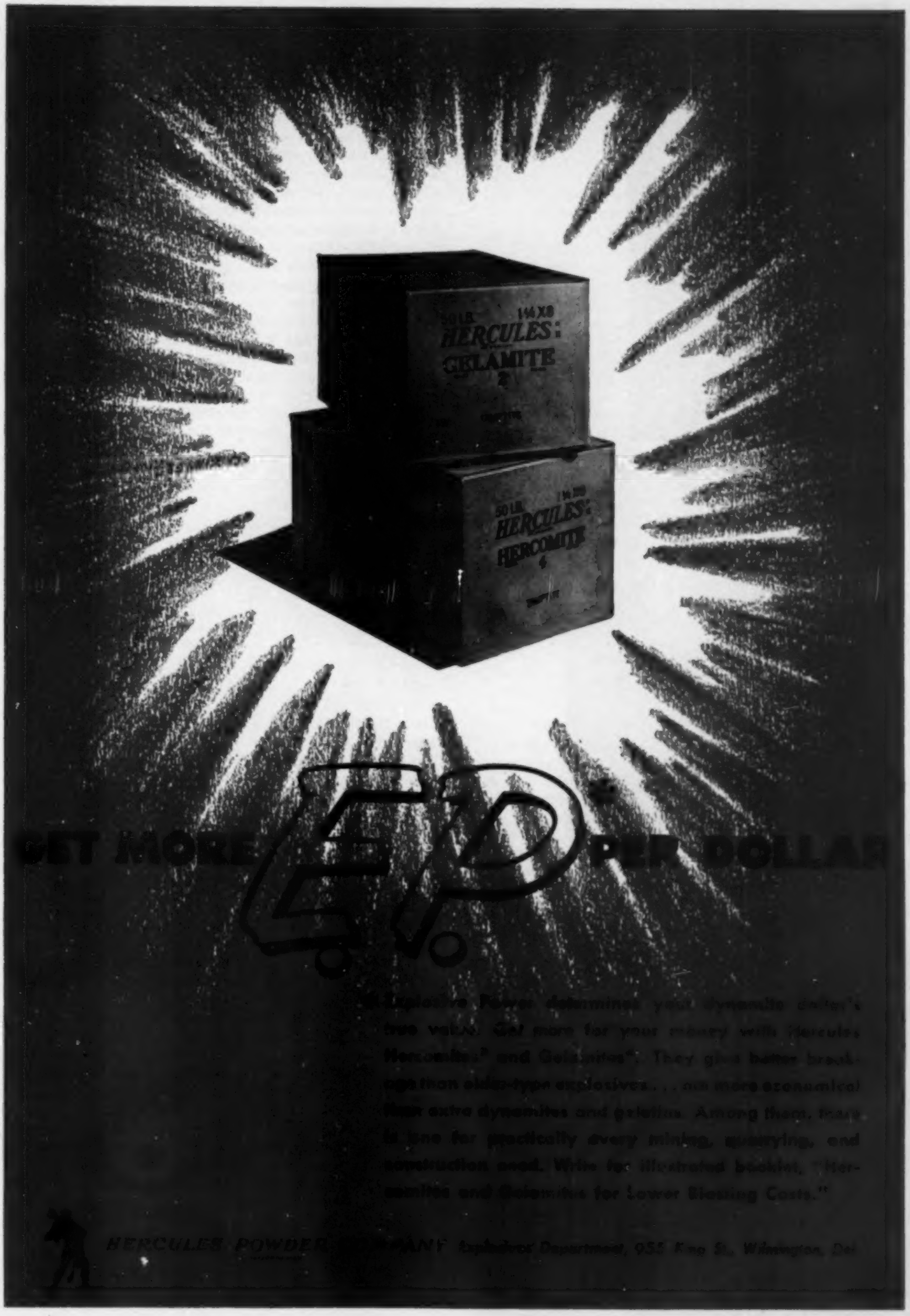
CARSET JACKBIT

Ingersoll-Rand

11 Broadway, New York 4, New York

632-15

ROCK DRILLS • COMPRESSORS • AIR TOOLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL & GAS ENGINES



50 LB. 1¼ X 8
HERCULES
GELAMITE
2
50 LB.
HERCULES
HERCOMITE
4
GET MORE E.P.* PER DOLLAR
Explosive Power determines your dynamite dollar's true value. Get more for your money with Hercules Hercomites and Gelamites*. They give better breakage than older-type explosives . . . are more economical than extra dynamites and gelatins. Among them, there is one for practically every mining, quarrying, and construction need. Write for illustrated booklet, "Hercomites and Gelamites for Lower Blasting Costs."
HERCULES POWDER COMPANY Explosives Department, 955 King St., Wilmington, Del.

Trends

John T. Whiting, president, Alan Wood Steel Co.
Does not fear the entrance into the Philadelphia area of the steel Goliaths.

Utah Copper Employees
Manipulative tests are one of a battery of six aptitude exams to qualify for advancement.

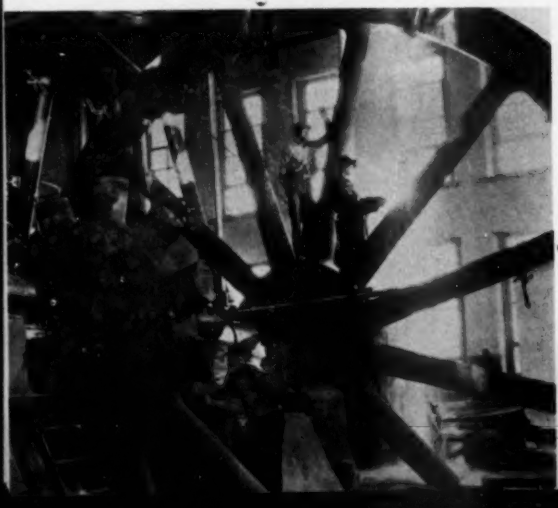
CHARLES E. WILSON'S second quarterly report "Meeting Defense Goals" was encouraging on the outlook for the mining industry, as prolonged demand for minerals seems assured; but for the individual engineer things are not so rosy. Ten percent of the gross national product is going for defense but the gross national product has been increased by 9 pct since the national emergency was declared—apparently a commendable rate of progress. The increased production does not seem to have had the stabilizing effect on prices it should and housewives have been revising domestic budgets upward on a quarterly basis. Government economists have reached the conclusion that more taxes and wage and salary freezing are necessary to counteract inflation.

The defense program is still in the "tooling-up-stage" but deliveries of end-items have now reached a level of \$1.5 billion monthly which is scheduled to reach \$4 billion monthly ten months hence. Currently on the books are \$42 billion worth of orders for military supplies with the President requesting \$49 billion for the fiscal year which began July 1. Because defense expenditures will rise to 15 pct of the gross national product by the end of 1951 and approach 20 pct in 1952, *business investment in industrial expansion will continue at high levels in the coming months.* Almost keeping pace with this increase in consumption of the national product by the military is an anticipated percentage increase in the national product of 10 to 12 pct of the current level.

Of the 440 World War II defense plants held in reserve, 278 are now producing defense items and another 66 are being reactivated. Included are seventeen plants for the production or fabrication of aluminum, twelve for magnesium, five for alloy metals, and one for copper. The steel industry is now producing at the rate of 108 million annual ingot tons which is in excess of rated capacity. The 1953 goal for steel is 118 million tons. Alloying metals, most of which are procured from abroad, are in short supply and their use will have to remain restricted largely to defense uses. The target for aluminum production has been raised to about 1.5 million tons per year.

Mr. Wilson considers the Controlled Materials Plan (CMP) to be the basic device for channeling vital materials to their most essential uses. CMP covers three metals—steel, aluminum, copper. As the demand for these three metals is brought into balance with supply, the pressure of demand on the short supplies of other materials is expected to be reduced. A defense producer receives a certified allotment of controlled materials and a priority rating for other materials needed for his production on the basis of approved production schedules. He is assured of his amount of controlled materials but restricted to that amount for the given time period. The manufacturer in turn distributes part of his allotment to his subcontractors.

Mr. Wilson's progress reports are encouraging be-



Old Wheels Are Useful to Defense
Administrative officials of industrial plants can help maintain steel production by writing off obsolete machinery on inventory and shipping it for scrap.

cause they reflect the vigorous pulse of American industry. But on the other hand, they give the reader such a good understanding of the objectives that it is possible to detect the Administration when it flags from zealous enterprise to political chicanery. Such an example is the negligence of the Price Stabilization Board in not rolling back prices prior to June 30 (the expiration date of the 1950 National Defense Act) while concurrently creating a clamor for strong price rollback authority in the new defense bill. The Stabilization Board had this authority under the old act but presumably the Administration preferred to let Congress take on its shoulders the political repercussions of this controversial issue. Although many good men and true are now giving their time to the government to work out the knots in the defense program, the final say is in the hands of a handful of men controlled by the President. So don't be too hard on your friends in Washington.

BUSY Kennecott has taken time from its farflung mining enterprises and explorations to repair fences at home in the area of employee relations. The Utah Copper Division has for the past year and a half been giving employee training courses (to be described in Sept. MINING ENGINEERING). Results for this short period indicate decreased maintenance costs in some departments, better worker performance, and happier employees. Kennecott expects relief from the labor shortage through this program. The method of teaching is to write up detailed descriptions of each job as a basis for teaching the individual job operations. **Manipulative tests are one of a battery of six aptitude tests qualifying employees for advancement.** Operating improvements have been suggested by employees taking the courses. It may be that Kennecott and others who get into this work will find it worthwhile to put an engineer to studying the job descriptions for better methods. As the labor situation gets tighter, more mining companies will be resorting to employee training. The Bureau of Apprenticeship of the U. S. Department of Labor will supply technical advice and assistance in setting up apprenticeship programs to train young men for the skilled labor force, and, it will aid in establishing skill-improvement programs to increase the abilities of all employees.

ALTHOUGH several oil companies have announced their intention of going into commercial production of refined products from retorted shale oils within the next decade, no negotiations for government assistance have been made. This is contrary to current rumors which have mentioned Union Oil Co. in this connection. Nevertheless, government officials are of the opinion that the time is opportune for an undertaking of this sort as domestic production of petroleum products will be lagging consumption substantially within the next few years and the Defense Production Act provides partial security for the investment in such an undertaking. Results of research work indicate good chance of economic operation of a plant for making crude shale oil. A $333,870 contract has been awarded Blaw-Knox Construction Co., Pittsburgh, Pa., for design and erection of a new demonstration oil-shale retort at Rifle, Colo. Said Boyd Guthrie, chief of the Oil Shale Demonstration Plant at Rifle: "If the new retort operates as anticipated, we have excellent chances of producing crude shale oil at a cost competitive with natural petroleum."

THE Alan Wood Steel Co. of Conshohocken, Pa., celebrated in July the 125th anniversary of its founding. Although it is one of the smallest in the steel industry, it is one of the most aggressive and independent; and, as its survival in this day of corporate giants would indicate—hardy!

The same family that founded the concern, now in its sixth and seventh generation, is still the resident-owner and actively associated in the management. Located 20 miles northwest of Philadelphia along the banks of the Schuylkill River, its coke ovens, blast furnaces, open hearths, rolling mills, metallurgical laboratory, and offices extend over 300 acres of rolling countryside and with its iron ore mines in New Jersey comprise an integrated unit with a payroll last year of $12½ million.

Moreover this little company **does not fear the entrance into the Philadelphia area of the steel Goliaths that have announced plans to develop plants there.** A measure of the confidence of the company in the future is the $21 million expenditure for improvements and expansion made in the last five years. A 30-in. hot roll strip mill, the first of its kind in eastern Pennsylvania, was put in operation. The first water treatment plant in the steel industry was recently constructed by the company to treat effluents from its plants on the Schuylkill. A project is under way to boost ingot capacity by about 10 pct which will necessitate enlargement of its New Jersey iron mines.

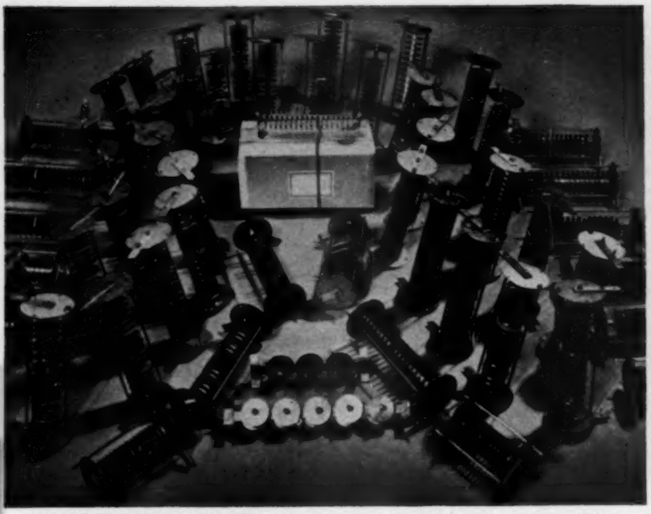
The company's strength lies in its specialty products which are shipped all over the United States and the world. "Permaclad," its stainless clad steel which combines the surface characteristics of stainless steel with the forming qualities of carbon steel, and "Algrip" in which an abrasive grain has been rolled into a floor plate to make it non-slip, are two of the mainstays of the company's specialties.

Congratulations Alan Wood and many more anniversaries.

SUPPLIES of heavy industrial iron and steel scrap are dangerously low. Several steel companies have less than two weeks inventory on hand. Some have only a few days supply. Others have already lost some production, either through downtime or because the use of inferior grades of scrap has not permitted maximum output per ton of raw materials used.

Recognizing the seriousness of the threatening scrap shortage, a special program is being conducted by the National Production Authority to seek out dormant scrap and place it in normal channels as quickly as possible. Government (Federal, State and Local), business, industry and agriculture have been asked to cooperate.

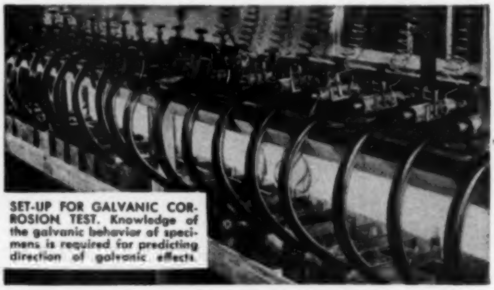
This is not a household scrap drive like some conducted during World War II. It is aimed rather at management and administrative officials who are in a position to make policy decisions that will assure quick action in (1) the collection of random heavy scrap, and (2) the writing off of idle, obsolete machinery and equipment. Your **old wheels are useful to defense.** Canvass your plant for scrap and make sure that it goes quickly to normal scrap channels.



SPOOL-TYPE SPECIMEN HOLDERS permit testing several materials under service conditions without risk of mechanical damage. Specimens make no contact with each other or with plant equipment . . . thus, galvanic effects are prevented.

ASSEMBLING A CORROSION TEST SPOOL. Specimens are machined to specified dimensions, and expose exactly 0.5 sq. dm. when mounted for test.

Help for solving your INDUSTRIAL CORROSION PROBLEMS...



SET-UP FOR GALVANIC CORROSION TEST. Knowledge of the galvanic behavior of specimens is required for predicting direction of galvanic effects.

Available for solving your specific problem is a vast amount of information on industrial corrosion.

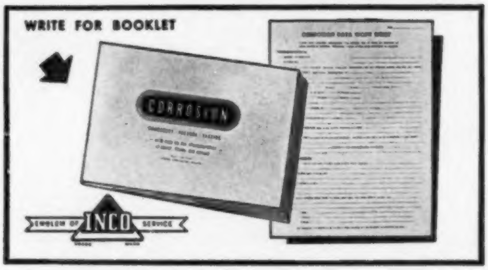
Acquired and catalogued by The International Nickel Company's Corrosion Engineering Section, this fund of data is constantly being increased.

Valuable information is obtained in various ways...for instance, by cooperative field tests in which specimens are exposed to actual plant operating conditions. Also, by fundamental investigations in the laboratory and by tests that duplicate, so far as practical, existing or expected conditions where plant tests are impractical.

A great deal of important data comes from INCO's large scale marine testing stations at Kure Beach and Harbor Island, and from stations having industrial and rural atmospheres. In addition, technical literature, reports, and manufacturer bulletins contribute useful information.

Our files contain data from more than 2,000 plant tests on some 40,000 metal and alloy specimens. All information is tabulated on standard forms, and a punch card key sort system facilitates finding specific data.

We freely provide the Corrosion Data Work Sheet, illustrated, for presenting your specific problems.



Whenever you need assistance in solving a corrosion problem, our Corrosion Engineering Section will gladly cooperate with you. A free copy of the new booklet entitled "Corrosion" may help you defeat corrosive attacks...write for it now.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Reynolds Jamaica Mines, Ltd., has received a $3½ million loan from ECA for the development of what are termed the largest bauxite deposits in the world in Jamaica, B.W.I. This amount is in addition to $11 million already provided. The new agreement calls for delivery of 750,000 tons a year beginning in early 1952.

Inco has announced a new alloy containing 35 pct Ni which can be used for many purposes served by the old alloys which ran up to 70 pct Ni. The new alloy "Incoloy" is 35 pct Ni, 20 pct Cr, and the balance iron.

In agreement with the United States Government, the Belgian tin mining company "Geomine" is to set up a pilot plant for the production of lithium - key metal for the hydrogen bomb - following the discovery of rich lithium deposits at Manono, Belgian Congo. Plans are already underway for a larger plant.

A $7½ million expansion program for the mining and beneficiation of 300,000 tons of nonmagnetic "martite" ore has been proved through the pilot plant stage and is ready for full scale construction at the Benson mines of Jones & Laughlin Steel Corp.

Development has begun on what are described as the biggest uranium deposits discovered on this continent. Production from the new deposits which are at Beaver Lodge Lake in Saskatchewan is expected to exceed by several times that of the Great Bear Lake property. The property is being operated by the Eldorado Mining & Refining Co.

Calcium carbide and ferroalloy output are to be doubled at the Portland, Ore., plant of the Electro-Met Div. of Union Carbide & Carbon Corp. New electric furnace units and buildings will be added to the facilities.

Chrome concentrates from New Caledonia are to be sold to the U. S. stockpile by arrangement with Lehman Bros., and the New Caledonia Co. of Calmet. These concerns are receiving $737,000 of ECA money for expansion of facilities.

The largest class in the history of Montana School of Mines was graduated in June. B.S. degrees were awarded to 56 and master's degrees to 9.

Freeport Sulphur Co. has warned domestic consumers that a cut in its present allocation rate of the strategic mineral will be necessary if the government should continue to direct large shipments abroad in the face of the prospect of increasing demands at home.

MINING ENGINEERING

EDITORIAL

PAINTING SCREENS

IT just so happens that we do our best thinking while painting woodwork and last Saturday while finishing up the screens (the bugs come late where we live) the paint very nearly ran out. By adding turpentine, it just stretched. It was pretty thin for the job though, which made us think that that is just about what the situation is going to be in the mining industry if something isn't done to increase the number of enrollments in engineering curricula. Engineers are going to be spread too thin for the job at hand.

Right now personnel managers know that there is a shortage of engineers because during the four years of World War II there were not many men in school. This has built up a backlog of jobs. If screens aren't painted for a couple of years they deteriorate. Putting on heavy coats later doesn't change the weakness in the structure. We may have caught up on engineers with the large GI enrollments after the war but in the area of supervisors, designers, and managers for new jobs with tough engineering problems, there are not enough men who have the drive for the job and yet have the youth with its accompanying vigor and also the experience.

A situation similar to this but worse is in the making. The depression of the '30s caused a decline in the birth rate and it is this generation which is now becoming of college age. Since this new generation is smaller numerically, engineering enrollments are falling off.

The problem can not be brushed over lightly because as the years go by and labor costs increase and lower grade orebodies are being worked the need for engineers increases. The relationship between the increase in the number of engineers and the growth of physical volume of mineral products (exclusive of the war years) shows alarming departures when the curves are projected through to 1955. The volume of mineral product is increasing but the number of engineers is not.

Fortunately it is not necessary for us to stand by and watch this shortage become increasingly acute. By working on local career guidance committees, it is possible to steer qualified young men into the engineering courses at college. This is part of the professional responsibility of every engineer. As an industry however, a little color should be brushed on the screens—call this public relations if you prefer. Color will get more people to look in and, remember, its screens not fences we're painting. Mining has lagged behind most fields in this important work of giving the general public some insight into the nature of the business.

Then there is the subject which we have touched on previously—improved placement policies. A good placement policy spreads good will rapidly and attracts the best talent. Mining companies need engineering graduates of top calibre because of the complex technology. These can be attracted to the mining field when employment officers can offer good pay, training courses, systematic review of salaries and work progress, and most of all interesting work and a chance for self-expression. These things all go with the progressive company.

Tom Sawyer is about the only fellow who got anyone to paint by bluffing. These are screens we're painting and we will have to do the job ourselves—as individuals and as an industry.

Covering resources, production, uses, defense impact, and future outlook of nickle, Mining Engineering *presents the third in a series of articles on strategic minerals. Preceding it are "Cobalt" in January and "Sulphur" in May.*

IT was no surprise when an important NPA official harried by distribution problems remarked that "four times the current supply of nickel is needed to sustain the defense program". True as this statement is, much of the additional nickel supply in question would go begging unless supplies of other basic raw materials and production capacity were increased similarly. Nevertheless, since the discovery that nickel added to steel made good armor plate, nickel has been essential to defense. In the interim between World War I, when this important property of nickel was battle-tested, and the Korean-prompted national emergency, the myriads of nickel alloys developed made that metal as basic in the variety and number of its uses as plastics. From the kitchen to rockets, nickel is universal in its applications.

Nickel supplies are now being stretched by *use limitation* orders and substitutes. And nickel producers are delivering only to the extent of allocations made each month by the National Production Authority. Large markets for nickel have been built up in non-military uses, and the nickel is being diverted from these to the defense effort. Amended NPA order M14 issued on Feb. 28, 1951 contained a list of 380 items from motor cars to kitchen utensils in which nickel is prohibited. Another cushion for the nickel pinch is the large mothballed fleet, which will reduce nickel consumption considerably in the marine field. All of the 7200 tons of nickel available monthly is earmarked for defense; but an allotment of 15 pct of the monthly average consumption during the first six months of 1950 is allowed for some consumer businesses which are stringency cases. How long this allotment can be maintained is not known. Defense orders are being skimped since suppliers have been directed not to deliver over 60 pct of the nickel called for by rated orders.

Faced with the tight nickel supply situation, Washington officials dubiously are contemplating Sudbury, Ontario, the nickel basket of the world. Although ubiquitous to metal products, nickel in economic ore deposits is exceedingly rare. Sudbury is the notable exception. The area has produced for over 50 years, yet it has been supplying 80 pct of world consumption since 1942.

Approximately 90 pct of the nickel mined at Sudbury is by the International Nickel Co. of Canada—familiarly known as Inco—and the remainder by Falconbridge Nickel Mines, Ltd.

As nickel deposits go, the Sudbury ores are considered lavish—copper, nickel, and platinum metals, gold, silver, selenium, and tellurium—there is nothing comparable known in the world. However, Inco does not regard this opulence with embarrassment for the original discovery at Sudbury in 1856 was hailed as a copper bonanza. Exuberance over the discovery was shortlived, for the first shipments of copper concentrates to Orford Copper Co. refinery at Bayonne, N. J., disclosed the hitherto unsuspected presence of nickel. As the miners of Saxony had learned over 100 years earlier, the white metal produced was brittle and unworkable. The Saxons

This article was prepared by John V. Beall from information received largely from the staffs of the U. S. Bureau of Mines, National Production Authority, and the International Nickel Co. The opinions are those of the author.

named it *Old Nick's copper* and went on to other things, whereas their sturdier successors devised the Orford process, which causes the sulphides of nickel and copper to separate by the addition of sodium sulphate to the melt. By 1900, business was fair but the market for nickel was small, about 10,000 tons annually. Its use was restricted to coinage, electroplating, and German silver. More uses for nickel were needed if the full potentialities of the discovery were to be exploited, because there was nearly 2 lb of nickel for every 1 lb of copper.

The race for naval power at the beginning of the century, coupled with a discovery by a Frenchman that the addition of nickel to steel increased its toughness, was the combination that boomed the nickel market. The United States Navy became the No. 1 consumer of nickel for armorplate for warships. Armament consumed 90 pct of the nickel during World War I and the Sudbury mines expanded phenomenally—44,000 tons per year. So it was that, suckled in war, the infant nickel suffered childhood diseases from the postwar slump in nickel demand. These diseases left their mark for never afterward was nickel, even in maturity, prone to overexpand the Sudbury basket. Fortuitously, the United States turning from war entered a decade of industrial expansion—the automotive age—which brought a new demand for nickel. These many new uses for nickel did not emerge full grown, but instead were in large part the hard, diligent work of Inco's research organization, built up by Robert Crooks Stanley.

Quite properly the growth of world nickel consumption to 158,700 short tons in 1950 can be considered a monument to the work of Mr. Stanley. Of this amount, 77 pct comes from Sudbury. The statistical story of world nickel production for the past 10 years, Table I, emphasizes the fact that capricious Nature gave such an advantage to the Sudbury ores that production elsewhere is insignificant. Russian production is significant, of course, in direct ratio to the likelihood that it will be thrown back at us in high velocity projectiles.

It is customary to refer to past records when seeking a solution to current problems and so Table II provides a study of United States' imports from the various countries of the world during the critical decade 1940 to 1949. Imports from Canada averaged about 74 pct. The results of United States efforts to stimulate nickel from Cuba and other countries to meet the demands of the war years seems small in comparison to the total need. Current United States nickel consumption at the annual rate of 86,400 tons is roughly 10,000 tons less than World War II average total imports.

There is pressure to bring nickel deliveries to the average for the war years, but even this will leave consumer business dormant. Defense production plus business as usual is not in the cards for nickel.

Nickel forms with many metals alloys of varying physical properties which have innumerable applications in manufacturing. Mention of some of these uses explains the high rate of nickel consumption in defense production. Table IV briefs the record of the consumption, composition, properties, and uses of nickel and its alloys. The chief consumers of nickel are the austenitic chromium-nickel steels, which are known for their resistance to corrosion. Chromium is responsible for the corrosion resistance and nickel acts as an austenitic stabilizer. The 18 Cr 8 Ni steels and the modifications of this basic composition constitute two thirds of all the production of stainless steel. The volume of nickel going into stainless steels places them under careful scrutiny by NPA for conservation. For steels requiring extra resistance to atmospheric corrosion but not requiring deep

Inco's Frood-Stobie pit supplied over 40 pct of the company's ore production during the war years. By 1953 the pit will be exhausted but the transition will be complete and 13 million tons of ore annually will be coming from underground.

Table I. World Nickel Production 1941-1950 Net Tons*

	1941	42	43	44	45	46	47	48	49	50
World	178,600	174,200	184,100	173,100	159,800	135,600	154,300	166,500	160,900	158,700
Canada	141,126	142,603	144,007	137,297	122,564	96,061	118,625	131,738	128,688	123,055
USA	660	612	642	988	1155	352	646	883	790	913
Cuba			2679	5158	12,015	12,301	2220			
Brazil		1		7	66					
French Morocco			50	52						
Rhodesia										
South Africa	558	593	544	593	554	548	583	505	625	829
Finland	107	1797	9888	345	992	686	595			
Germany	743	636	1048							
Greece	204	778	546							
Italy	100	82	47	15	13					
Norway	1080	1004	638	583	569	61				
Sweden	111	416	774	769	430					
USSR	15,000	12,130	12,330	14,330	14,770	22,000	27,550	27,550	27,550	27,550
Burma	519									
Japan	2547	1380	1778	1806	716					
Australia										
Indonesia	1323	1323	1323							
New Caledonia	11,458	10,378	8128	8945	4771	3063	3687	5381	3716	6945

* Table taken from *Materials Survey on Nickel* by Perry N. Moore, U.S. Bureau of Mines.

drawing properties, nickel can be eliminated by increasing the chromium. For all other purposes, downgrading to a lower nickel content and prohibition of the uses of stainless steel in the manufacture of many nonessential articles offer the best opportunities for conservation. Enamel-coated carbon steel might be substituted for stainless in exhaust pipes of some internal combustion engines at moderate temperatures and under conditions of low stress.

Where corrosion is the chief problem, rather than resistance to heat, the stainless clad steels may be substituted for stainless. This product is applicable in many food processing and chemical industries requiring tanks and heavy equipment, but might not be useful where light sheets form the bulk of such articles.

The addition of nickel (up to 9 pct) to plain carbon steels adds greatly to strength, hardness, and toughness, as evidenced by the classic experiments in penetration of battleship armor by projectiles. Such steels contain 0.15 to 0.45 pct carbon and manganese in varying amounts.

For conservation purposes, nickel can be eliminated from cast armor. Metallurgists have had plenty of experience substituting the National Emergency steels for standard compositions. The so-called NE steels curtailed consumption of strategic metals in the alloy steels or those containing a maximum of 5.25 pct Ni and up to 1.50 pct Cr as chief alloying metals. For example, the NE 8000 series listed by AISI had the following ranges: 0.15 to 0.52 pct C; 0.70 to 1.00 pct Mn; 0.15 to 0.40 pct Mo; 0.40 to 0.60 pct Ni; and 0.40 to 0.60 pct Cr. This change from high to low alloy steels is predicated on making the best possible use of the available alloying elements in small quantities and on the utilization of alloy steel scrap to best conserve these elements. The program in World War II saved 40 pct of the primary nickel consumed for this use. During World War II segregation of alloy steel scrap became the most important source of Ni and Cr in the NE steels, reducing the amount of primary nickel consumed. Scrap generated by the production of war materials was increasing the nickel content so that the upper limit of Ni was set at 0.70 pct. The changeover to NE alloys was not made without overcoming consumer conservatism. Metallurgical complications were created by the variety of alloying elements turning up in scrap, which caused difficulty in melting single-alloy batches. Recent in-

Table III. Salient Nickel Statistics for 1950*

United States:		
Production		
Primary	short tons	800
Secondary	short tons	N.A.
Imports (gross weight)[1]	short tons	98,560
Exports (gross weight)[2]	short tons	3,598
Consumption	short tons	
Price per lb[3]	cents	48-51½
Canada		
Production	short tons	123,055
Exports	short tons	N.A.
World Production	short tons	158,700

[1] Excludes "All other manufactures of nickel" weight not recorded.
[2] Excludes "Manufactures" weight not recorded.
[3] Price quoted to United States buyers by International Nickel Co., Inc. for electrolytic nickel in car lots.
* Table adopted from *Minerals Yearbook*, "Nickel" chapter by Hubert W. Davis.

Table II. United States Imports of Nickel, by Country of Origin, 1940 to 1949*
(Nickel content in net tons estimated)

Year	Amount	Canada Pct of Total Exports	U.K.	Norway	Netherlands	USSR	Union of South Africa	Cuba	Sweden	New Caledonia	Mexico	Other	Total
1940	83,478.4	67.0	227.3	53.8									83,759.5
1941	99,493.2	72.4	269.7							6,418.6			106,181.5
1942	106,521.3	76.8	236.7							7,496.9	20.1		114,275.0
1943	116,865.8	86.1	65.2							5,560.5			122,491.5
1944	107,520.0	80.5	793.8					2,956.9		7,022.3			118,293.0
1945	87,042.2	80.5	3,205.9					12,785.4		4,399.5			107,433.0
1946	81,392.8	73.1	440.7	5.0				10,660.6				0.9	92,500.0
1947	73,389.5	62.7	371.1	1,754.5		55.1		5,113.8	31.4			2.1	80,717.5
1948	92,332.7	70.0	833.4	3,112.6	9.2	57.4	28.4					26.3	96,400.0
1949	86,347.6	67.9	1,221.5	3,786.2	98.0							17.7	91,471.0
Total	934,383.5	73.9	7,665.3	8,712.1	107.2	112.5	28.4	31,516.7	31.4	30,897.8	20.1	47.0	1,013,522.0

* Table taken from *Materials Survey on Nickel* by Perry N. Moore, U.S. Bureau of Mines.

Table IV. Consumption and Properties of Nickel by Commodities in 1949

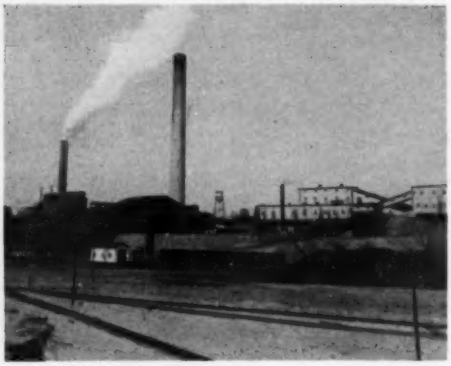
Commodity	Consumption Tons	Pct of Total	Composition Pct	Properties	Uses
Ferrous:					
Stainless steel	11,908.6	17.4	18% Cr, 8% Ni	strength and corrosion resistance	automobile body & engine parts, food handling & chemical equipment, construction materials, kitchen appliances
Other steels	13,474.2	19.7	Up to 5.25% Ni; C, Mn, Mo, Ni, Cr	toughness, strength	armorplate, structural & engineering purposes, gears, transmissions, rock drills, basic in military equipment
Cast irons	3396.2	5.0	Up to 5% Ni	toughness, strength, uniformity, machinability, corrosion resistance	pump parts
Nonferrous:					
Malleable nickel	18,971.4	27.8	94% Ni	toughness, hardness, strength, corrosion	food processing & chem. equip., cyanide fusion pots, television, radio, coinage, boilers, furnaces
Duranickel			94% Ni, 4.3% Al	same as malleable nickel nickel	coil springs, hand tools, flexible diaphragms, pump parts, extrusion dies for plastics
Permanickel			94% Ni, .33% Ti, .30% Mg		
Monel			67% Ni, 30% Cu, Mn, Fe	noted for corrosion resistance, strength, hardness	food, chem., petroleum, & pharmaceutical industries; laundry, hospital & kitchen equipment; marine service; household and architectural, ornamentation
Cupro-nickel			70% Cu, 30% Ni	corrosion resistance	heat exchanger tubes, steam turbine blades, coinage
German-silver			10-30%, 5-30% Zn, 1-10% Pb, balance Cu	beauty, workability, corrosion resistance	ornamentation, flatware, jewelry, food equipment, marine fittings, musical & dental instruments
Inconel			80% Ni, 13% Cr 7% Fe	resistance to corrosion at high temperatures. Will withstand repeated heating and working without embrittlement	petroleum refining, dairy, wine, fruit juice, caustic alkali, fatty acid, dyestuff, edible oil industries
High temperature and electrical resistance alloys	4053.9	5.9	See Table V	strength and corrosion resistance a' high temperatures	furnace construction, carburizing boxes, high speed tools, gas turbine & jet engine high-temp. parts
			35-85% Ni, Cr, Fe	electrical resistance	wire in stove, heaters, household and industrial uses
			15-30% Ni, Al, Co	good magnetic properties	alnico magnets
			25% Ni, Fe	nonmagnetic	transformers, motors
			45-80% Ni, Fe	highly magnetic	generator parts, electrical sheathing for submarine cable, radio, transformers, telephone & telegraph relay parts
			36% Ni, Fe	low thermal expansion	measuring tapes, precision instruments, matches, auto engine pistons, wire for wire glass
Electroplating:					
Anodes	13,810.4	20.2		resistance to atmospheric corrosion	decorative trim & industrial protection
Solutions	724.3	1.1			
Catalysts	497.1	0.7	Raney nickel prepared by leaching aluminum out of a granular Ni-Alloy	catalyzes the hydrogenation of unsaturated hydrocarbons and other organic compounds to saturated ones	catalyst for artificial aging of liquors, drying oils, bleaching, waste water, purification, dehydrogenization and polymerization of organic compounds, the removal of organic sulphur compounds from coal, gas
Ceramics	149.6	0.2			
Other	1340.4	2.0			
Total	68,326.1				

formation on the use of intensifiers or addition agents indicates that boron can effectively replace nickel in the low alloy steels to the extent of 0.003 to 0.005 pct B for 1 pct Ni.

Second only to steels, the nonferrous alloys are a big consumer of nickel and in this era of jet engines, gas turbines, and rockets, this use will grow. In normal times the use of nickel for plating is usually right on the heels of nonferrous alloys consumption-wise. Various nonferrous alloys are described in Table IV, but to elaborate on the high temperature or refractory alloys, the elite of the nonferrous group, Table V is added. Mr. Wilson has called for 18,000 jet engines per month by 1953, which means some tall substituting for nickel will have to be worked out if this objective is to be reached. Some substitutions that have been worked out for the nonferrous group include that of stainless steel for Inconel in certain uses; and carbon steel clad with nickel, Monel, Inconel for food and chemical processing equipment.

Starting June 1 all melting schedules must be approved by the Ferroalloys Branch of National Production Authority. Approximately 3000 rolled steel and foundry companies are reporting melting schedules about one month in advance of working so that the NPA staff can check the composition of melts to maintain minimum consumption of strategic metals. The end-use of each melt is listed so that NPA can evaluate the specification. In the case of Munitions Board Specifications, NPA has the authority to recommend downgrading, which the Board can only countermand by proving necessity.

Headframe of the No. 5 shaft of the Falconbridge mine which has been producing nickel-copper ores for over 20 years.



The ores are reduced to a copper matte at the concentrator and smelter above and shipped to a refinery at Kristiansand, Norway.

Inspecting melting schedules enables NPA to make sure industry is not working in advance of schedule, which might cause shortages on orders requiring immediate delivery.

In addition to rigid control of the available nickel supply, the Government is closely scrutinizing world resources of the metal in the hope of finding a new producer. Nickel deposits of the world occur in association with basic intrusives. Three types of deposits are known; nickel-copper-sulphide deposits accounting for over 95 pct of the world's production, nickel silicate ores which are commercially important in New Caledonia, and nickeliferous iron ores like those from Nicaro, Cuba. The world's reserves of commercial sulphide ore are substantial—about 30 years known—but they are limited. The sulphide ores are being mined in significant amounts in Sudbury district, Canada; and by USSR in Petsamo, Finland. Sulphide deposits exist also in the Transvaal and Griqualand, South Africa; and Yakobi Island, Alaska; but these deposits have not been worked commercially.

Before the turn of the Century the silicate ores were the chief source of nickel. Besides New Caledonia there are significant occurrences in Minas Gerais, Brazil; the Celebes, Indonesia; Loma de Hierro, Venezuela; and Riddle, Ore.

The largest potential reserves are those of nickeliferous iron deposits, which contain about 1 pct Ni. These are highly disseminated in iron-rich material and are costly to recover. These ores have been exploited in Cuba by a United States Government sponsored project during World War II, but other unexploited deposits are in the Celebes, Greece, Japan, Philippines, and Russia. Tables VI and VII show the reserves of world nickel resources.

At Sudbury, a basic intrusive called norite occurs in the form of a basket-shaped body 36 miles long by 26 miles wide (Fig. 2). The nickel deposits occur along the margins of this eruptive and as offset deposits associated with small necks of basic intrusion away from the margins. The nickel is in the form of pentlandite (Fe, Ni) S associated with pyrrhotite.

Copper occurs in the form of chalcopyrite with a subordinate amount of platinoids. The tenor of the larger deposits ranges from 0.8 to 2 pct each of nickel and copper in varying proportions. Reserves

Table V. Nonferrous Heat-resistant Alloys*

Designation	Ni	Cr	Co	Mo	Fe	Other
Castings:						
HP†	30	30			Remainder	
HT	36	15			Remainder	
HU	39	19			Remainder	
HW	61	12			Remainder	
HX	67	17			Remainder	
Hastelloy A	57			20	20	
Hastelloy C	58	15		17	5	W,5
61: Stellite 23	2	23	Remainder		1	W,5
6059: Stellite 27	32	23	Remainder	6	1	
422-19: Stellite 30	16	23	Remainder	6	1	
X-40; Stellite 31	10	23	Remainder		1	W,7
Cast or wrought:						
Hastelloy B	65			30	5	
S-816	20	20	43	4	Remainder	W,4;Cb,4
Vitallium; Stellite 21-	2	27	Remainder	6	1	
Wrought:						
N-155	21	21	21	3	Remainder	W,2;Cb,1;N,0.1
S-590	20	20	20	4	Remainder	W,4;Cb,4
Inconel X	73	15			7	Cb,1;Ti,2.5;Al,0.7
K-42-B (type 5)	42	18	22		13	Ti,2.6;Al,0.6
Refractaloy	37	18	20	3	17	Ti,3;Al,0.25

† Alloy Casting Institute designation.
* Table taken from *Materials Survey on Nickel* by Perry N. Moore, U.S. Bureau of Mines.

Table VI. Estimated Nickel Reserves of Sulphide Ores of the World as of Jan. 1950, in net tons[*]

Place	Equipped		Unequipped	
	Ore	Nickel Content	Ore	Nickel Content
Canada				
Falconbridge	14,791,000	254,500		
Inco	251,805,000			
Lynn Lake area			10,365,000	149,600
Union of South Africa				
Rustenburg				
Vlackfontein	[1]	[1]	150,000	4500
Insizwa			[1]	[1]
United States				
Alaska			22,000,000	70,000
U.S.			14,000,000	70,000
USSR				
Petsamo	4,000,000[2]	64,000[3]	[1]	[1]
Kola & Novilsk region	[1]	[1]	[1]	[1]

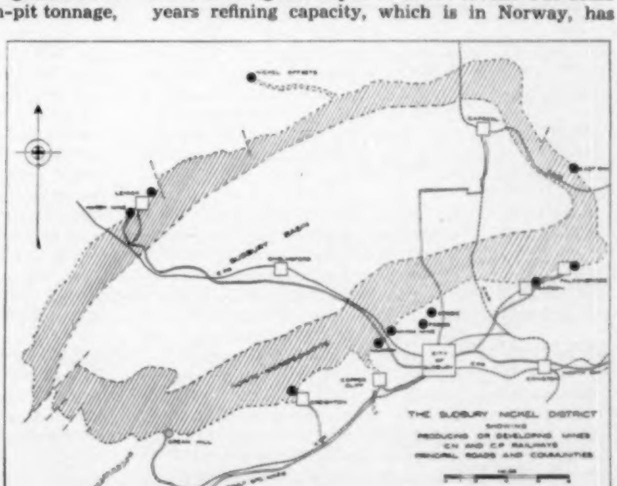
[1] Data not available.
[2] 7,630,000 tons Ni-Cu, ratio of Ni-Cu not available.
[3] Data prior to operation by USSR, in round numbers.
[*] Materials Survey-Minerals *Nickel Reserves of the World* by H. R. Cornwall & W. S. Burbank, USGS.

of the two major companies operating here are sufficient for about 20 or 30 years at present rate of production, but it is doubtful if further discoveries would increase the annual output of the district.

Inco is operating the Levack on the north margin, and the Creighton, Murray, and Garson mines on the south rim of the basin. The Frood-Stobie, the biggest of them all, is an offset orebody occupying a norite dike south of the main norite intrusion. To meet the demands of World War II, the Frood-Stobie open pits were brought in at an accelerated rate and production quickly boosted from 6000 to 20,000 tons per day, 40 pct of total ore produced by the company. As a consequence of the heavy war drain on the pits it is estimated that they will be exhausted by 1953. The current inflated demand for nickel has come when the open-pit ores are nearly exhausted and no new orebodies capable of being brought into quick production by open-pit methods are available. However, underground ores are being developed to replace the open-pit tonnage, and by 1953 the transition will be completed without interrupting current production during the transition period. Indeed 13 million tons will then be produced from the underground mines, a greater tonnage than ever came from the combined underground mines and open-pit operations. It will be necessary to mine lower grade ores and to accomplish this, cheaper mining methods had to be adopted. Blasthole mining with long drill holes and block caving are being studied; the former method for the Stobie and Murray mines and the latter at the Creighton.

An increase in nickel output of about 5 pct, or 6000 tons annually has been reached. In 1950 the company delivered 256,410,543 lb of nickel, as compared to 209,292,257 lb in 1949. This was a record for any previous peacetime year. The record deliveries for all time were made in 1943 and amounted to 265,389,323 lb. Inco's reserves have remained at 250 million tons for several years in spite of mining at the rate of 12 million tons annually. To retain these reserves, the company is doing extensive exploration at Sudbury and elsewhere. Exploration is being pushed at Shebandowan Lake, Ont., about 60 miles west of Port Arthur where about 1 million tons averaging less than 2 pct Ni have been found. The company has holdings at Loma de Hierro, Venezuela, which have favorable mining and transportation conditions although the deposit being a silicate, presents metallurgical difficulties. A tract 10 to 12 miles long and ½ mile wide underlain by serpentine is reported to have 30 million tons of 1.75 pct Ni. No work is in progress at this location.

Falconbridge is now producing from two properties, in the Sudbury area, the Falconbridge and the McKim mines on the south rim of the norite mass; and is making plans to produce from the Hardy mine on the north rim adjoining to the Levack mine of International Nickel. The McKim only recently has become a producer, whereas the Falconbridge has been productive for about 20 years. Recent diamond drilling shows ore to persist to 5700 ft, over twice the depth of present mining. The latter mine is being developed at lower levels. For some years refining capacity, which is in Norway, has



Black dots indicate the mines of the famous Sudbury basin, source of 80 pct of the world's nickel. The squares are the various towns.

lagged matte production in Canada but by October 1951 enough additional capacity will be in service to increase output from the 1950 rate of about 12,000 tons to 15,000 tons. Concentrating and smelting facilities are being added to coincide with expanded refinery capacity. However, the company is embarking on a further expansion program, which will bring production up to 20,000 tons per year in three years after the program commences—say 1954. Additional mill and smelter capacity will be needed and the refinery, with slight additions will be able to handle 17,500 tons. The remaining matte will go elsewhere for refining.

Refining has been done in Norway because of the advantageous electric power rates, but strategic considerations are causing pressure for a refinery in Canada. Thayer Lindsley, president of Falconbridge, thinks that if this becomes a necessity, the company should not bear the full expense. Reserves for the Falconbridge and McKim mines are 9,369,000 tons of 1.60 pct Ni and 0.86 pct copper, and indicated reserves of close to 6 million tons of 1.86 pct Ni and 1.03 Cu for the company's Sudbury holdings. Falconbridge holds additional parcels of land in the Sudbury district and drilling shows favorable mining areas; but an increase in price would be helpful to further expansion. There are a number of nonproducing properties in the area owned by these two companies and by other companies, including the Nickel Offset, Junior Frood, East Rim, Sudbury Shepherd, and the Crean Hill, some of which are under development.

A major discovery of sulphide ores made in recent years is the Lynn Lake deposits of northern Manitoba, about 200 miles north of Flin Flon by Sheritt Gordon Mines, Ltd. Nickel-copper ore reserves of about 14 million tons were delimited but more would have been found by continued exploration. An estimated $28 million will be spent to bring the deposit into production by 1954 at the rate of 2000 tons per day from the two highest grade deposits. The ore averages 1.44 pct Ni and 0.68 pct Cu. Production plans call for an objective of 8500 tons of Ni, 4500 tons of Cu, 150,000 lb of cobalt, and 70,000 tons of ammonium sulphate fertilizer per year. The concentrator, mine plant, and housing will be taken from Sherridon to the new project at Lynn Lake. Copper concentrates will be shipped to the smelter at Flin Flon, but a nickel refinery will be constructed in Alberta and will be completed by the latter half of 1953. A 150-mile railroad is required for full scale mining and the Canadian National Railroad already has commenced the survey for it. A substantial portion of the nickel, copper, and cobalt is under a 5-year contract with the U. S. stockpiling agency with deliveries to start in 1954.

Other nickel deposits of unknown reserves occur in Ontario, the Bird River district of Southern Manitoba, and British Columbia. Most promising is a nickeliferous deposit near Choate, B. C., where diamond drills have disclosed 1 million tons that contain 1.3 pct Ni and 0.4 pct Cu.

The only known sulphide deposits in the world comparable in size to a small Sudbury deposit are in northern Finland at Petsamo. International Nickel did all the pioneer mine development and equipped the property with smelter and refinery capable of producing 15 million lb of nickel annually. How-

Table VII. Estimated Nickel Reserves of Silicate and Nickeliferous Iron Ores of the World as of Jan. 1950, in net tons*

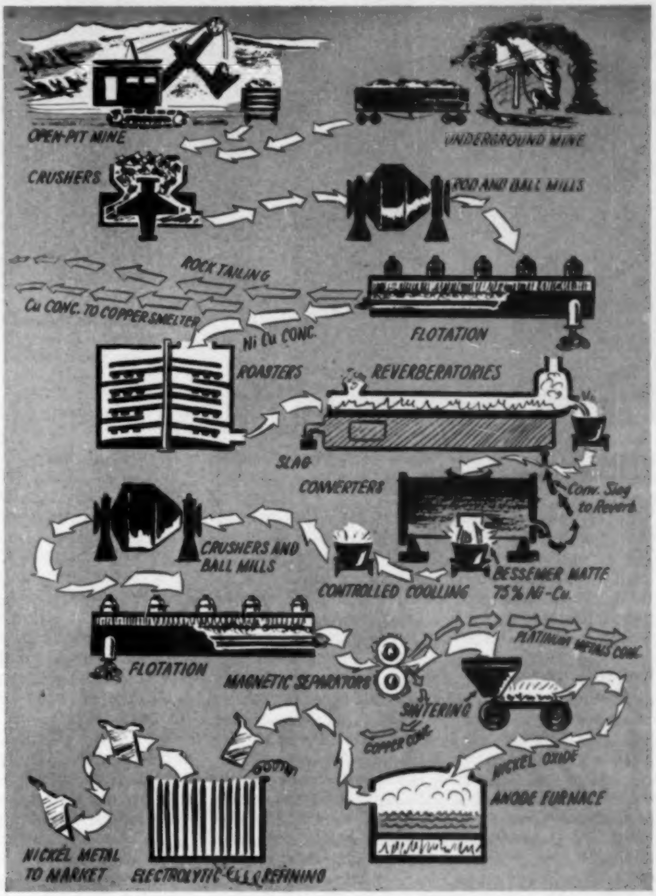
Place	Equipped Ore	Equipped Ni	Unequipped Ore	Unequipped Ni
Silicate & nickeliferous iron ores				
Brazil (silicate)				
Tocantins, Goias			10-18,000,000	200-360,000
Livramento & Ipanema Minas Gerais			4,000,000	40,000
Cuba				
Levisa, Oriente (Fe-Ni)	27,700,000	401,600		
Mayari, Moa, Oriente (Fe-Ni)			3,000,000,000	24,000,000
San Felipe, Camagey (Fe-Ni)				
Greece				
Atlante-Larymna (silicate & Fe-Ni)			10,000,000	50-100,000
Idonesia				
Bornea (Fe-Ni)			200-500,000,000	1-3,000,000
Celebes				
Pomalea-Kolaka (silicate)			2,000,000	60,000
Lakes Region (silicate)			1,000,000	20,000
Lakes Region (Fe-Ni)			370-500,000,000	3-4,500,000
Japan (Fe-Ni)			63,000,000	315,000
Madagascar				
Nickelville (silicate)			900,000	3,280[2]-43,000
Nickeliferous iron ores			[3]	[3]
New Caledonia (silicate)	[4]	[4]		
Philippine Islands				
Surigao (Fe-Ni)			550,000,000	4,400,000
U. S. (silicate & Fe-Ni)			40-45,000,000	400,000
USSR (silicate & Fe-Ni)	[3]	[3]	[3]	[3]
Venezuela (silicate)			30-50,000,000[1]	450-875,000[5]

[1] Including "serpentine" ores.
[2] Estimated recoverable nickel in garnierite ore only.
[3] Data not available.
[4] Sufficient to maintain production 12,000 metric tons of Ni per year for 80 years.
[5] Data from *Northern Mine*.
* Materials Survey-Minerals *Nickel Reserves of the World* by H. R. Cornwall and W. S. Burbank, USGS.

NICKEL RECOVERY FLOWSHEET

40,000 tons per day of Ni-Cu sulphide ores from Inco mines go to a new 10,000 ton concentrator at Creighton and to the concentrator at Copper Cliff. The ore runs between 0.75 and 1.5 pct each of Cu and Ni. It is cone and roll crushed, and ground in rod and ball mills. Flotation yields a bulk concentrate and then separate Cu and Ni-Cu concentrates. The bulk concentrate from Creighton is pumped 7½ mi. to Copper Cliff for differential flotation. Cu concentrate is sent to the smelter. The Ni-Cu concentrate is roasted in Nichols-Herreschoff roasters superimposed on reverberatory furnaces, and the gas goes to Cottrell precipitators. The reverb matte containing 13 pct Ni-Cu is blown in convertors, yielding a Bessemer matte with 75 pct Ni-Cu.

This matte is cooled and subjected to comminution, flotation, and magnetic separation to produce Cu sulphide, Ni sulphide, and platinum concentrates. Ni sulphide is sintered on Dwight-Lloyd machines to produce a Ni oxide sinter. This sinter is reduced and melted in anode furnaces, cast into anodes, and electrolytically refined.

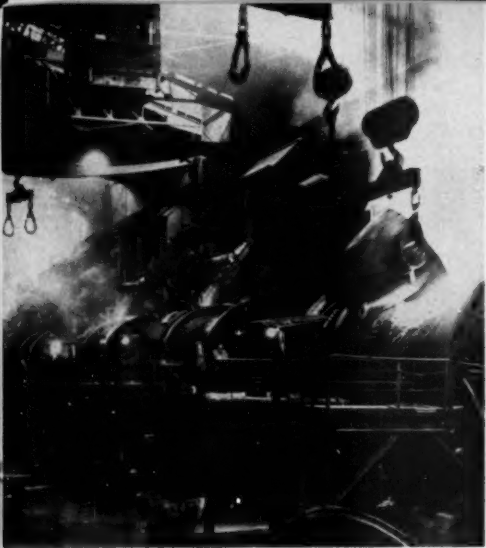


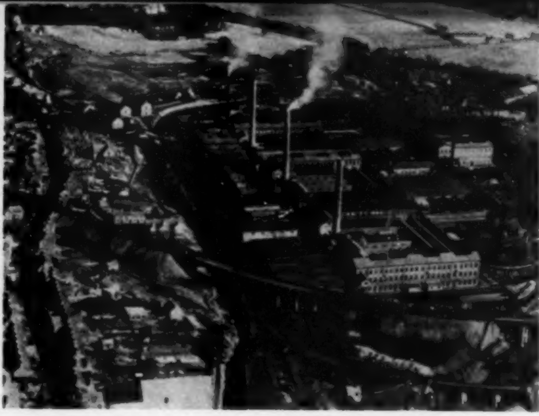
ever, the Russians annexed the area in 1944 and agreed to compensate Inco to the extent of $20 million. The reserves of this district are reported at 64,000 tons of nickel but are probably much greater. Other deposits of importance are at Nivala in southwestern Finland, Norilsk area of Northwest Siberia, and at Monechegorsk on the Kola peninsula. There are also silicate and nickeliferous ores in the central and southern Urals at Ujoli, Revda, Orsk and other places, which average 2 pct Ni. Soviet nickel is controlled by a state monopoly, Glavnickelkobalt, which can probably produce nickel from ores not considered economical by western standards. Soviet nickel production should not exceed 19,000 tons annually.

In 1949, La Societe le Nickel, a French controlled company, produced ore containing 3700 tons of nickel from the nickel silicate deposits of New Caledonia. In recent years, New Caledonia ores have dropped to the position of producing about 2½ pct of the world's nickel. The decline in importance has been the result of the exhaustion of high grade ores and the increased costs of production by primitive methods. In addition, coal for the smelter must be imported from Australia. La Societe le Nickel expects to receive $965,000 from ECA for purchase of heavy mining and conveying equipment, which should bring production to 11,000 tons. Part of this would come to the U. S. in payment of the loan. Reserves are estimated to be sufficient to maintain a production rate of 13,000 tons annually of nickel for 80 years.

The existence of low grade nickel deposits in large quantities at the eastern end of Cuba has been known for many years, but prior to World War II no economic process had been developed for extracting nickel from such ores. These deposits are nickeliferous iron ores, carrying minor amounts of chromium and cobalt in addition to nickel.

However, with war impetus over 32,500 tons of nickel were extracted from these deposits at the peak rate of over 12,500 tons annually. Before mining began, reserves were estimated at 24 million tons of 1.45 pct Ni and between 35 and 40 pct Fe. However, 3 million tons were mined from 1942 to early 1947 when the operation was shut down. Practically the whole of Oriente province is underlain by the laterite formation containing nickel in





Converters are used for both nickel and copper smelting at Copper Cliff, Ont., by Inco. Some of the nickel oxide sinter is sent to Clydach, Wales, for making nickel metal by the Mond process.

varying amounts. One estimate is 3 billion tons of nickeliferous iron ore reserves averaging 0.8 pct nickel.

The Freeport Sulphur Co., having rights to some of the better grade deposits in 1942 when OPM put nickel under allocation order, formed the Nicaro Nickel Co. A plant was constructed after clearing the jungle on the coast using $32 million of RFC money. It was necessary to bring in labor from the populated areas and construct living accommodations.

Selective mining of ore by open pit methods yielded a plant feed of 1.45 pct Ni content. At the plant, the ore was crushed and dried and then ground to a fine mesh in hammer and ball mills. The fine, dry ore so obtained was reduced by producer gas in 16-hearth, oil-fired Herreshoff furnaces, the product being leached in an ammonia solution from which the nickel is precipitated in the form of nickel carbonate. This was calcined to nickel oxide and was at first shipped to a refinery in Wilmington, Del., where it was briquetted with reducing and fluxing agents and converted to nickel metal in electric furnaces. By great effort the company was able to get consumer acceptance of the oxide particularly for electric furnace steels. The speed with which this operation was brought into production was a tremendous feat and Nicaro nickel supplied relatively small but important amounts of nickel for the war effort.

The orebodies are still owned by Freeport and the plant is again being rushed into production, but this time by the Mining Equipment Corp.-Billiton interests, on behalf of the General Service Administration. It is hoped to bring the plant to 16,000 tons of nickel annual production rate. At the outset, the same metallurgical treatment will be used but metallurgical studies are in progress for the recovery of cobalt from the pregnant liquor of the ammonium leaching system, probably by fractional crystallization. The mine will produce 5000 wet tons per day, which is dryed to produce 3600 tons of plant feed. The first production is expected by 1952.

Probably the largest basic intrusion in the world, the Bushveld Complex, is located in the Union of South Africa at the north end of the Transvaal. Nickel occurs in small amounts at the Merensky reef, from which it is being recovered as a by-product of platinum mining by the Rustenburg Platinum Mines, Ltd., and the Vlackfontein deposits about 38 miles northwest of Rustenburg from which there is no production. Both orebodies are sulphide and the former produced 618 metric tons of contained nickel in matte. Also at Insizwa, Griquiland, in the Union of South Africa, there is a basic intrusion with considerable pyrrhotite. Several adits have been run in this deposit but the nickel content was too low to justify development.

In a 14-square mile area in the state of Goias, Brazil, there are about 50 near-surface deposits of nickel silicate, which aggregate 22 million tons of 1 to 4.5 pct nickel. The area is about 1000 miles from Santos, the nearest port, and neither labor, fuel, nor water power is available. Some nickel is mined by a Brazilian firm and it is reported that a Canadian company has a concession.

There are large reserves of silicate and nickeliferous iron ores in the Celebes, Netherlands East Indies, from which some small production has come. About 10 million tons of 1 to 3 pct nickel silicate ores are known in the Pomalea district. The lakes region has about ½ a billion tons of nickeliferous iron ore running 49 pct Fe and 0.9 pct Ni.

A small amount of nickel comes from Norway, Germany, Finland, Greece, Burma, India, and Japan, in addition to the producing bodies and occurrence of nickel named.

At present there are no economical nickel deposits in the United States. Somewhat less than 1000 tons has been produced annually, varying in amount from year to year, as a by-product from copper refining and also from talc production. The Riddle nickel silicate deposit in Douglas county, Ore., has been drilled by the USGS and was under consideration by the Freeport Sulphur Co. during the last war. The M. A. Hanna Co. is now exploring the property and is conducting a metallurgical investigation on a laboratory scale to determine the possibility of an eventual production of several million lb of nickel per year from the property. The deposit is favorably situated for low cost mining being near surface on the slopes of Nickel Mountain. Reserves have been roughly estimated from 40 million tons containing 1 to 2 pct Ni.

Nickel Processing Facilities of the World*

Processing Plant	Location	Capacity and Comments
Inco	Copper Cliff, Ont.	Produce salts, chem. & matte. Smelter
	Port Colborne, Ont.	200 million lb capacity electrolytic nickel per yr
	Coniston, Ont.	Smelter only
	Clydach, Wales	Refinery 80 million lb cap. Salts, chem. and Ni metal
	Huntington, W. Va.	Refinery, operates in conjunction with fabricating plant at same location. Processes New Caledonia matte
Falconbridge	Sudbury, Ont.	Smelter 23,000 tons matte capacity, 1950
	Kristiansand, Norway	Refinery—capacity being increased. Prewar 11,000 tons Ni
USSR	Norilsk	2,000 tons per yr Ni
	Orsk, Urals	Smelter & refinery, 1939 reported at 10,000 tons pr yr Ni
	Ujaloi	Refinery. Capacity 1939—2500 tons per yr Ni
	Rieij	36,000 tons Portable Knock-down type smelter
	Petsamo, Finland	Smelter. 600 tons per day capacity when operated by Germans
Nord Deutsche Affinerie	Hamburg, Germany	66,000 tons per yr capacity smelter
Finnish Govt.	Pori, Finland	Smelters. 500 to 600 tons per yr
	Frankenstein, Germany	An old smelter which processed the ore from Lokris, Greece
Krupp-Renn	Magdeburg, Germany	Produces Ni-Fe in pellet form in a rotary tube furnace
I. G. Farben	Oppau, Germany	Ni powder from matte by Mond process where nickel is separated from matte in form of carbonyl $(Ni(Co)_4)$. Produced 17,000 tons per yr of Ni powder during World War II
Societe Le Nickel	Noumea	Smelter about 9000 tons per yr matte cap.
	New Caledonia	Plans under way to increase capacity to 15,000 tons of matte containing 11,000 tons Ni by four KVA furnaces.
	Le Havre, France	Prewar refinery-treated matte from New Caledonia
Societe Caledonia	Duffel, Belgium	Prewar refinery-treating matte from New Caledonia
Burma Corp.	Northern Shan States Burma	Smelter producing speiss containing 100 tons Ni per yr which was sent to German refinery
	Japan	Prewar smelter & refinery which treated New Caledonia ore plus low grade local deposits. Estimated 700 tons per yr Ni capacity

* Table taken from *Materials Survey on Nickel* by Perry N. Moore, U.S. Bureau of Mines.

Other occurrences of nickel are reported at Stillwater county, Mont., where about 1 million tons of a nickel-copper sulphide ore are favorably situated for mining; and also near Webster, Jackson county, N. C., there are discontinuous veinlets of nickel silicate bearing material amounting to 1 million tons of 1 pct or less nickel content. There is by-product nickel with the complex lead-zinc-copper-cobalt ores of Fredericktown, Mo., worked by the St. Louis Smelting & Refining Co. The cobalt-nickel concentrates are stockpiled but treatment of these has not begun. Only small amounts would be recovered in comparison to national consumption.

There are also nickel deposits in Skagit county, Wash., and in Alaska. An extremely low grade sulphide orebody associated with a basin shaped norite intrusive has been drilled by the Bureau of Mines and the USGS on Yakobi Island, Alaska, about 139 miles west of Juneau. Estimates are 10 million tons of 0.36 pct Ni and 0.27 pct Cu.

Development of silicate ores or the vast reserves of nickeliferous deposits in different parts of the world awaits depletion of Sudbury ores or an increased price for the metal. Previous experience with Nicaro proved this. The nickel oxide of Nicaro was produced at a small profit when only direct operating expenses were charged against production costs. Unless there are metallurgical improvements these deposits will not be competitive.

Inco is making the arduous changeover from accessible open-pit ore to underground mining and has added 5 pct capacity. Already $100 million have been spent in the past few years in changeover and further additions to capacity would require more millions, which are not warranted from a sound business viewpoint. With the dollar worth 48c of preWorld War II value, such expenditures would be burdensome should the defense effort collapse. For comparative purposes, Falconbridge built 10 million lb of nickel capacity for an expenditute of $3 million in the late 30's. A similar program today would cost three or four times that amount. The question of additional refinery capacity this side of the Atlantic has been examined thoroughly in Washington. The refinery is not likely as the United States will not construct one in Canada, and that nation frowns on the export of nickel matte to the U. S. for the excellent reason that nickel metal brings more dollars than matte. The U. S. reasoning is more obscure because this country is already spending vast sums through ECA abroad. If Mond refinery in Wales and the Norwegian refinery were destroyed or lost to an enemy, Inco would be stretched to the limit to handle the refining of this matte in Canada.

Sheritt-Gordon is going into the nickel business with both feet and without benefit of platinum values. Those close to the company say that their process for nickel recovery which is to be used will give them low cost operation and a competitive product.

The world has more sources of nickel than probably will ever be exploited. During the interim years of war, the International Nickel Co. and the few small producers are able to meet the world demand. During emergency periods, like the present there is a tremendous shortage of nickel but there are few sources that can be developed to meet this demand even with Government subsidization because they are vulnerable to wartime shipping hazards. Private development of some of the undeveloped sources is subject to meeting the competition of Inco once the emergency is relieved. Finally, subsidization of marginal deposits has not been done on a scale that would furnish relief under present conditions because of the large capital expenditure needed and the fact that the operation would not be economical in normal times. The pressure on nickel is not likely to abate until the defense buildup has been achieved.

Enrollment Study - - - -

Shows Decrease in Future Engineers

by WILLIAM B. PLANK

and

HENRY J. PETRIE

ENGINEERING educators and industries are worried about the engineering manpower shortage that is predicted as a result of the increasing demand for trained engineers not only by industry but by the armed services. This is in the face of a decreasing supply, as is shown by this and other studies. Not only has the number of entering freshmen been decreasing since 1947, because of a decrease in the number of high school graduates entering engineering, but the total number of high school graduates will continue to decrease until 1958 because of the lowered birth rate during the depression years.

The following summary of the tenth biennial survey of the mineral engineering schools of the United States and Canada, made under the auspices of the Mineral Industries Education Division of the AIME, indicates that there are 12,918 students enrolled in these schools in the current academic year 1950-51. This enrollment of 12,918 mineral engineers in both countries, shown in Tables I and II, is 14 pct smaller than the enrollment of 15,028 in 1948-49, the peak year, and is about the same size as it was in 1946-47. The decrease since 1948-49 was 13 pct in the United States schools and 30 pct in the Canadian schools. The data for these comparisons are shown in Table IV. In the United States 37 pct of the mineral engineering students are veterans as compared with 67 pct of the group in 1948-49. Seventeen women are studying to be mineral engineers in the United States but none in Canada.

The total engineering enrollment in the United States and Canada during the academic year 1950-51 was 184,547, as is shown by the data from the ASEE given in Table III. This represents a decrease of 27 pct from the enrollment of 249,915 in 1948-49. By comparing these figures with those given in the preceding paragraph, it is seen that the mineral engineering group has decreased in size only about one half as rapidly as the whole engineering group.

Table V shows that next June there will be approximately 35,000 engineering graduates, and in June, 1952, there will be 25,000. In addition, the 54,500 men who received their first degrees in engineering in June, 1950, have been absorbed by industry, and all branches of engineering have been listed as critical by the Secretary of Labor. In the light of these facts, it is easy to foresee the shortage in the supply of engineers that is alarming government and industrial officials.

Not only are engineers vitally needed by industry, but in this present national emergency all branches of the armed services have been taking their toll of engineers through the Selective Service, by enlistments and by the recall of reservists. As has been pointed out by a number of educators and

MESSRS. PLANK and PETRIE are head, Department of Mining and Metallurgical Engineering and instructor in mining, Lafayette College, Easton, Pa.; Member and Junior Member AIME, respectively.

Table I. Mineral Engineering Student Enrollment By Courses, 1950-1951. United States, 64 Schools.*

Course	Fresh.	Soph.	Jrs.	Srs.	Total Under Grads.	Grad. Stds.	GRAND TOTAL	Candidates B.S. Deg.
Mining	386	413	465	511	1,775	115	1,890	480
Metallurgical	544	598	656	754	2,552	626	3,178	749
Pet. & N. Gas	701	680	801	932	3,114	144	3,258	856
Ceramic	158	171	222	280	831	123	954	274
Geology	442	447	605	658	2,152	418	2,570	618
Fuels	7	12	9	14	42	25	67	14
Specials					102		102	
TOTALS	2,238	2,321	2,758	3,149	10,568	1,451	12,019	2,964

* Data from 10th biennial survey by Mineral Industry Education Division, AIME, November 15, 1950.

Table II. Mineral Engineering Student Enrollment By Courses, 1950-1951. Canada, 8 Schools.*

Course	Fresh.	Soph.	Jrs.	Srs.	Total Under Grads.	Grad. Stds.	GRAND TOTAL	Candidates B.S. Deg.
Mining	62	55	65	100	282	1	283	103
Metallurgical	41	34	49	73	197	25	222	73
Pet. & N. Gas	8	18	27	26	79	0	79	26
Ceramic	1	1	6	10	18	0	18	10
Geological	47	41	53	78	219	78	297	80
TOTALS	159	149	200	287	795	104	899	292

* Data from 10th biennial survey by Mineral Industry Education Division, AIME, Nov. 15, 1950.

Table III. Engineering Enrollment by Classes and Courses, 1950-51, 190 United States and 7 Canadian Schools*

	No. of ECPD Schools	Fresh.	Soph.	Jrs.	Srs.	5th Yr. and Others	Tot. Under-Grads.	Grad. Stud.	Grand Total
Mining	31	286	335	401	473	17	1,312	95	1,607
Metallurgical	49	478	526	643	767	309	2,723	788	3,511
Pet. & nat. gas	23	690	666	786	995	30	3,167	154	3,321
Ceramics	13	127	169	189	268	27	780	106	886
Geological	22	238	300	304	341	6	1,239	110	1,349
Total ECPD min. Engineers in U.S.		1,869	1,996	2,333	2,834	389	9,421[a]	1,253	10,674
Chemical	106	2,686	2,921	3,147	3,695	1,168	13,617	2,706	16,323
Civil	130	3,886	4,836	5,574	6,490	1,673	22,449	2,086	24,505
Industrial	63	738	1,095	1,631	2,087	440	5,991	1,108	7,099
Mechanical	128	5,020	6,291	7,598	9,514	3,783	32,206	3,141	35,347
Electrical	133	4,793	5,727	6,742	8,453	3,330	29,045	5,060	34,105
Other Engineers		3,430	3,573	3,831	4,586	1,330	16,750	2,722	19,472
Unclassified	82	6,972	803	101	58	5,541	13,475	224	13,799
Total Engineers ECPD schools	142	29,394	27,242	30,957	37,707	17,654	142,954	18,370	161,324
Other U.S. schools	48	4,905	3,673	3,466	3,995	2,599	18,638	300	18,938
All U.S. schools	190	34,299	30,915	34,423	41,702	20,253	161,592	18,670	180,262
Canadian schools	7	806	763	908	1,153	514	4,144	141	4,285
U.S. and Canada GRAND TOTAL	197	35,105	31,678	35,331	42,855	20,767	165,736	18,811	184,547[b]

* Data from *Journal of Engineering Education*, Feb., 1951.
[a] Includes 17 women.
[b] Includes 696 women.

representatives of industry in the congressional hearings on the pending universal military training bill, it seems plain that to maintain our national defense, both in industry and in the armed services, there should be a continuing supply of college-trained engineers.

As to a prediction of the supply of mineral engineers in the United States and Canada, it is seen in Table V that the number of men receiving their first degrees in that field has increased from 2,881 to 3,256, or 13 pct in two years, as compared to a decrease of 25 pct in all engineering graduates in the same period. This June it is expected that 3,256 men will receive their first or bachelor degrees in mineral engineering, but in the succeeding four years this supply will sharply decline unless something is done to stimulate enrollment in the field.

In addition to those receiving bachelor degrees in mineral engineering this June, an undetermined percentage of the 1,451 graduate students, shown in Table VI, will be available for positions. This group has increased in size 32 pct over two years ago, as compared to an increase of only 20 per cent in the whole engineering graduate student group.

Apropos of stimulating enrollment in mineral engineering, it is encouraging to note the increased efforts in this direction. Especially commendatory and worthy of support is the proposal presented by the Minnesota Section of the AIME at the annual meeting at St. Louis "to study the means of encouraging youth to study in the mineral engineering field."

Of the 2,964 mineral engineers to receive their first degrees this June in the United States schools, 480 were in mining, 749 in metallurgy, 856 in petro-

Table IV. Engineering Student Enrollment by Courses, Undergraduates and Graduates (1940-41 to 1950-51)

	(1) 1940-41	(1) 1944-45	(3) 1946-47	(1) 1947-48	(1) 1948-49	(1) 1948-49	(1) 1949-50	(2) 1950-51	(4) 1950-51
Mining	1,978	224	2,302	2,459	2,236	2,632	2,223	1,607	1,800
Metallurgical	2,450	472	3,170	4,121	4,055	4,156	3,887	3,511	3,178
Pet. and Natural Gas	2,877	376	3,048	4,665	4,533	4,147	4,175	3,321	3,258
Ceramics	843	190	940	1,108	1,206	1,214	998	886	964
Geology	792	?	?	?	?	2,777	?	1,349	2,870
Fuels	44	?	?	?	?	47	?	?	67
Specials	149	?	?	?	?	53	?	?	102
Total Mining Engineers U. S.	....	....	....	....	....	13,769	11,283	10,674	12,019
Canada	....	....	....	....	....	1,259	....	....	899
U. S. & Canada	9,133	1,292	9,469	12,353	12,056	15,028	....	....	12,918
Chemical	....	5,082	23,600	26,972	23,610	....	19,976	16,323	....
Civil	....	3,537	20,079	31,849	33,961	....	29,109	24,505	....
Mechanical	....	6,965	44,403	56,551	53,642	....	45,632	35,347	....
Electrical	....	5,934	38,963	56,408	53,774	....	45,711	34,105	....
Others	....	18,832	66,475	68,117	72,969	....	68,001	59,308	....
Total Engineers Canada							6,821	4,285	
Total Engineers, U. S. & Canada	114,116	41,632	222,557	252,230	249,915	....	226,528	184,547	

(1) *Mining Engineering*, May, 1950.
(2) *Journal of Engineering Education*, February, 1951.
(3) *Mining Engineering*, *Journal of Metals* and *Journal of Petroleum Technology*, August, 1949.
(4) Study of Mineral Education Division, AIME, November 15,1950.

Table V. First Degrees, All Engineers, United States and Canada*

1942-43	14,714
1943-44	11,155
1944-45	4,724
1945-46	8,219
1946-47	19,272
1947-48	30,018
1948-49	46,934
1949-50	54,441
1950-51	35,000•
1951-52	25,[illegible]0•

* Data from *Journal of Engineering Education.*
• Estimated.

leum and natural gas, 274 in ceramics, 618 in geology, and 14 in fuels. The industrial placement officers were on the college campuses offering jobs since before the first of the year and a government agency actively sought to employ mining engineers. One large industry announced several months ago that it would hire all engineers that would apply. There is an encouraging increase in the n[illegible]mber of graduate fellowships available, especially to metallurgical engineers. What are needed now, however, are more undergraduate scholarships such as those available through the Coal Division of the AIME, the National Coal Association, and several other industrial organizations.

For the first time, this report includes, in Table VII, the distribution of the instruction staff in the mineral engineering schools of both countries. In the 64 United States schools, the staff numbered 875, and in the 8 Canadian schools the number was 150. It is of interest to observe that the objectives of the MIED would be materially furthered if all of these would participate actively in its program.

Table VI. Distribution of Graduate Students in Mineral Engineering, United States, 1933-1934 to 1950-1951*

	33-34	34-35	36-37	38-39	40-41	42-43	46-47	48-49	50-51
Mining	40	55	49	44	44	20	70	82	115
Metallurgical	116	93	131	172	215	137	470	552	626
Petroleum and Natural Gas	18	29	58	43	75	27	187	91	144
Ceramics	19	36	48	64	50	19	138	104	123
Geology	46	62	34	86	127	9	127	197	418
Fuels	4	10	18	6	9	10	16	16	25
Totals	243	285	338	415	520	222	1008	1102	1451

* Data from Mineral Industry Education Division, AIME, Studies.

Table VII. Faculty of Mineral Engineering Schools, 1950-1951, United States

	Profs.	Assoc. Profs.	Asst. Profs.	Instrs.	Assistants	Others	Grand Total
UNITED STATES							
Mining	43	20	22	12	13	3	113
Metallurgical	78	51	45	56	69	31	330
P. & N. Gas	22	13	19	13	32	4	103
Ceramic	31	14	20	11	17	0	93
Geology	55	35	41	36	56	8	231
Fuels	0	2	1	1	0	0	5
TOTALS, U.S.	229	136	148	129	187	46	875
CANADA							
Mining	11	5	4	3	3	7	33
Metallurgical	11	4	1	2	4	13	35
P. & N. Gas	0	0	1	1	1	0	3
Ceramic	1	0	0	0	0	1	2
Geology	18	5	13	4	22	15	77
TOTALS, Canada	41	14	19	10	30	36	150

Directory of Mineral Engineering Schools in the United States and Canada

** Accredited by ECPD, September, 1950*

THE name and address of the school are given, followed by the length of the regular undergraduate curriculum, the degree granted, types of courses given, and the name of the man in charge. This covers only work for the first or Bachelor degree in each case. School catalogs should be consulted for details.

The following abbreviations are used:

A. Arts, **B.** Bachelor, **Cer.** Ceramics or Ceramic, **E.** Engineer or Engineering, **Eng.** Engineering or Engineer, **Eco.** Economic, **Geol.** Geologist, Geological, or Geology, **M.** Mines or Mining, **Met.** Metallurgy or Metallurgical, **Min.** Mineral, **Mng.** Mining, **M.S.** Master of Science, **Pet.** Petroleum, **Ref.** Refining, **S.** Science, **Tech.** Technology or Technical.

UNITED STATES

University of Alabama, University, Ala. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Met., (4) Cer., (5) Pet. Tech. James R. Cudworth, dean; J. W. Stewart, head, School of Mines; T. N. McVay, head, Dept. of Ceramics.

University of Alaska, College, Alaska. 4-yr. B.S. and 5-yr. B.Min.E. major in: (1) *Mng. Eng., (2) *Mng. Eng., Geol. option, (3) *Mng. Eng., Met. option. Richard C. Ragle, head, Dept. of Geology; Earl H. Beistline, head, Dept. of Min. & Met. and dean, School of Mines.

University of Arizona, Tucson, Ariz. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) *Mng. Geol. (4) *Geol. T. G. Chapman, dean, College of Mines.

Polytechnic Institute of Brooklyn, Brooklyn 2, N. Y. 4-yr. B.Met.E. Otto H. Henry, professor of Metallurgical Engineering.

University of California, Berkeley, Calif. 4-yr. degrees in: (1) *Mng. Eng., (2) *Met., (3) *Pet. Eng., (4) Mineral Exploration. Anders J. Carlson, chairman, Division of Mineral Technology.

Carnegie Institute of Technology, Pittsburgh, Pa. 4-yr. B.S. in *Met. Eng. Robert F. Mehl, head, Dept. of Metallurgical Engineering.

Case Institute of Technology, Cleveland, Ohio. 4-yr. B.S. in *Met. Eng. K. H. Donaldson, head, Dept. of Metallurgical Engineering.

University of Cincinnati, Cincinnati, Ohio. 5-yr. *Met. Eng. Cooperative. Dr. Roy O. McDuffie, professor of Metallurgy.

Colorado School of Mines, Golden, Colo. 4-yr. (1) *E.M., (2) *Geol. Eng., (3) *Pet. Eng., (4) *Met. Eng., (5) *Pet. Ref. Eng., (6) Geophysical Eng. John W. Vanderwilt, president.

Columbia University, New York, N. Y. 4 or 5-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Mineral Eng. Philip B. Bucky, prof. of Mining and Exec. Officer of Dept. of Mng., Met. and Min. Eng.

Cornell University, Ithaca, N. Y. 5-yr. B.Met.E. Fred H. Rhodes, director of the School of Chemical & Met. Eng.; S. C. Hollister, dean of the College of Engr.

Drexel Institute of Technology, Philadelphia 4, Pa. 5-yr. (co-operative) B.S. in Met. Eng. A. W. Grosvenor, professor of metallurgy.

Fenn College, Cleveland, Ohio. 4½-yr. cooperative in B. of *Met. Eng. Dr. D. C. Fabel, head, Dept. of Mechanical and Metallurgical Eng.

Georgia Institute of Technology, Atlanta, Ga. 4-yr. B. of *Cer. Eng.

Lane Mitchell, director, School of Ceramic Engineering.

Harvard University, Cambridge, Mass. Undergraduate instruction in engineering sciences and applied physics, or geological sciences, preparatory to professional study in Division of Engineering Sciences of the Graduate School of Arts and Sciences in: (1) *Physical Met., or in Division of Geological Sciences, (2) Min. Geol., (3) Pet. Geol., (4) Geophysics; or in the Dept. of Engineering Sciences and Applied Physics. Marland P. Billings, chairman, Division of Geological Sciences.

University of Idaho, Moscow, Idaho. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Geol., (4) *Geol. Eng. A. W. Fahrenwald, dean, School of Mines.

Illinois Institute of Technology, Chicago 16, Ill. 4-yr. B.S. in Met. Eng. Otto Zmeskal, director, Dept. of Metallurgical Engineering.

University of Illinois, Urbana, Ill. 4-yr. B.S. in: (1) *Cer. Eng., (2) *Met. Eng., (3) *Mng. Eng. H. L. Walker, head, Dept. of Mining and Metallurgical Engineering; A. I. Andrews, head, Dept. of Ceramic Engineering.

Iowa State College, Ames, Iowa. 4-yr. B.S. in: (1) *Cer. Eng., (2) Mng. Eng. G. L. Bridger, head, Dept. of Chemical and Mining Engineering; C. M. Dodd, head, Dept. of Ceramic Engineering.

University of Kansas, Lawrence, Kans. 4-yr. B.S. in: (1) Geol. Eng., (2) Met. Eng., (3) *Min. Eng., (4) Pet. Eng. R. M. Dreyer, Chm., Dept. of Geol. & Geological Eng.; K. E. Rose, Chm., Dept. of Mng. & Met. Eng.; and C. F. Weinaug, Chm., Dept. of Pet. Eng.

University of Kentucky, Lexington, Ky. 4-yr. B.S. in: (1) *Met. Eng., (2) *Mng. Eng. C. S. Crouse, head, Dept. of Mining and Metallurgical Engineering.

Lafayette College, Easton, Pa. 4-yr. B.S. in: (1) *Met. Eng., (2) *Mng. Eng. W. B. Plank, head, Dept. of Mining and Metallurgical Engineering.

Lehigh University, Bethlehem, Pa. 4-yr. B.S. in: (1) *Mng. Eng., (2) Mng. Eng., Eng. Geophysics option, (3) *Met. Eng. A. C. Callen, head, Dept. of Mining Engineering; Gilbert E. Doan, head, Dept. of Metallurgical Engineering.

Louisiana Polytechnic Institute, Ruston, La. 4-yr. curriculum in Pet. Eng. Roy T. Sessums, dean, School of Engineering.

Louisiana State University, Baton Rouge, La. 4-yr. B.S. in: (1) *Pet. Eng., (2) Pet. Geol. Henry V. Howe, director, School of Geology.

Massachusetts Institute of Technology, Cambridge, Mass. 4-yr. S.B. in *Metallurgy. John Chipman, head, Dept. of Metallurgy.

Michigan College of Mining and Technology, Houghton, Mich. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Geol. Eng. 5-yr. B. of Mng. E. Grover C. Dillman, president.

Michigan State College, East Lansing, Mich. 4-yr. B.S. in Met. Eng. L. G. Miller, dean of Engr.; A. J. Smith, head, Met. Eng.

University of Michigan, Ann Arbor, Mich. 4-yr. B.S.E. *(Met.). George G. Brown, chairman, Dept. of Chemical and Metallurgical Engineering.

University of Minnesota, Minneapolis, Minn. 5-yr. (1) *B. Mng. Eng., (2) *B. Geol. Eng., (3) *B. Pet. Eng., (4) *B. Met. Eng. T. L. Joseph, dean, School of Mines and Metallurgy.

Missouri School of Mines and Metallurgy, Rolla, Mo. 4-yr. B.S. in: (1) *Mng. Eng. with options in (a) Mng. Geol., (b) *Pet. Production; (2) *Met., (3) *Cer. Eng., (4) B.S., with major in Geol., Cer., or Met. B.S. in Chemical Eng. for those specializing in Pet. Refining. Curtis L. Wilson, dean.

Montana School of Mines, Butte, Mont. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) *Geol. Eng., (4) Pet. Eng. J. R. Van Pelt, president.

University of Nevada, Reno, Nev. 4-yr. B.S. in: (1) *Mng. Eng., (2) Met. Eng., (3) Geol. Eng. Dr. Vernon E. Scheid, dean, College of Mines.

New Mexico School of Mines, Socorro, New Mex. 4-yr. B.S. in: (1) Mng. Eng., (2) Met. Eng., (3) Pet. Eng., (4) Geol., (5) Geophysics. E. J. Workman, president.

New York State College of Ceramics, Alfred, N. Y. 4-yr. B.S. in: (1) *General Cer. Tech. and Eng., (2) Glass Tech. J. F. McMahon, dean.

North Carolina State College of the University of North Carolina, Raleigh, N. C. 4-yr. B. of: (1) *Cer. Eng., (2) Geol. Eng. W. W. Kriegel, head, Dept. of Ceramic Engineering; J. L. Stuckey, head, Dept. of Geological Engineering.

University of North Dakota, Grand Forks, N. Dak. 4-yr. B.S. in: (1) *Mng. Eng., (2) Geology. L. C. Harrington, dean, College of Engineering, director, Division of Mines and Mining Experiments.

University of Notre Dame, Notre Dame, Ind. 4-yr. B.S. in *Met. Edward G. Mahin, head, Dept. of Metallurgy.

The Ohio State University, Columbus, Ohio. 5-yr. (1) *B. Eng. in Mng., (2) B. Pet. Eng., (3) B. *Cer. Eng., option in Glass Technology, (4) B. *Met. Eng. Tell Ertl, head, Dept. Mine Engineering; J. L. Carruthers, head, Dept. of Ceramic Engineering; Mars G. Fontana, head, Dept. of Metallurgy; E. V. O'Rourke, professor of petroleum engineering.

University of Oklahoma, Norman, Okla. 4-yr. B.S. in: (1) Geol. Eng., (2) *Pet. Eng., (3) Natural Gas Eng. W. H. Carson, dean, College of Engineering.

Pennsylvania State College, State College, Pa. 4-yr. B.S. in: (1) Geol. & Mineralogy, (2) Geophysics & Geochemistry, (3) Meteorology, (4) Geography, (5) Mineral Eco., (6) *Mng. Eng., (7) Mineral Preparation Eng., (8) *Pet. & Nat. Gas Eng., (9) Fuel Tech., (10) *Met., (11) *Ceramics. Edward Steidle, dean, School of Mineral Industries.

University of Pennsylvania, Philadelphia 4, Pa. 4-yr. B.S. in Met. Eng. R. M. Brick, director, Dept. of Metallurgy.

University of Pittsburgh, Pittsburgh, Pa. 4-yr. B.S. in: (1) *Mng., (2) *Met. Eng., (3) *Pet. Eng., (4) Geol. Eng. H. E. Dyche, acting dean, Schools of Engineering and Mines.

Princeton University, Princeton, N. J. 4-yr. Geol. Eng., with degree B.S. in Eng. Kenneth H. Condit, dean, School of Engineering; W. T. Thom, Jr., chairman, Dept. of Geological Engineering.

Purdue University, West Lafayette, Ind. 4-yr. B.S. in *Met. Eng. G. M. Enos, chairman, Division of Metallurgical Engineering, School of Chemical and Metallurgical Engineering.

Rensselaer Polytechnic Institute, Troy, N. Y. 4-yr. (1) *B.Met.E., (2) B.S. Fuel Resources. W. F. Hess, head, Dept. of Metallurgical Engineering, R. F. Beers, head, Dept. of Fuel Resources.

Rutgers University, New Brunswick, N. J. 4-yr. B.S. in Cer. Engineering. John H. Koenig, director, School of Ceramics.

South Dakota School of Mines and Technology, Rapid City, S. Dak. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Geol. Eng. Warren E. Wilson, president.

University of Southern California, Los Angeles, Calif. 4-yr. B.E. in: *Pet. Eng., B.S. in Geology. C. R. Dodson, head, Pet. Eng. Dept., Thomas Clements, head, Dept. of Geology.

Stanford University, Stanford, Calif. 4-yr. B.S. in: (1) Geology, (2) Geochemistry, (3) Geophysics, (4) Met.E., (5) Min.E., (6) Pet.E. Charles F. Park, Jr., dean, School of Mineral Sciences.

Agricultural and Mechanical College of Texas, College Station, Texas. 4-yr. B.S. in *Pet. Eng. Also 5-yr.

(1) *B. Pet. Eng., (2) *B.S. in Pet. Eng. and Mech. Eng., (3) *B.S. in Pet. Eng. and Geol. Eng., (4) *B.S. in Pet. Engr. and Chem. Engr., (5) *B.S. in Pet. Engr. and Business. Harold Vance, head, Dept. of Petroleum Engineering.

University of Texas, Austin, Texas. 4-yr. B.S. in: (1) *Pet. Eng., (2) *Cer. Eng. H. H. Power, chairman, Dept. of Petroleum Engineering. F. K. Pence, head, Dept. of Cer. Engineering.

Texas Western College of the University of Texas, El Paso, Texas. 4-yr. B.S. in Mng. Eng. with options in: (1) *Mng. Eng., (2) *Met., (3) *Mng. Geol. Wilson H. Elkins, president; E. M. Thomas, dean of Mines and Engineering.

University of Tulsa, Tulsa, Okla. 4-yr. B.S. in (1) *Pet. Production Eng., (2) *Pet. Refining, (3) Pet. Geol., (4) Geophysical Eng. R. L. Langenheim, dean, College of Petroleum Sciences & Engineering.

University of Utah, Salt Lake City, Utah. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Geol. Eng., (4) Ceramic Eng. C. J. Christensen, dean, College of Mines and Mineral Industries.

Virginia Polytechnic Institute, Blacksburg, Va. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) Geol., (4) *Cer. Eng. E. B. Norris, dean of Engineering.

State College of Washington, Pullman, Wash. 4-yr. B.S. in: (1) Geol., (2) *Mng., (3) *Met., (4) Phy. Met. John P. Spielman, dean, School of Mines.

University of Washington, Seattle, Wash. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng., (3) *Cer. Eng. Drury A. Pifer, director, School of Mineral Engineering.

Washington University, St. Louis, Mo. 4-yr. B.S. in *Geol. Eng. Lawrence E. Stout, dean, School of Engineering.

West Virginia University, Morgantown, W. Va. 4-yr. B.S. in Mng. Eng., with options in: (1) *Mng. Eng., (2) Oil and Gas Eng. G. R. Spindler, director, School of Mines.

West Virginia Institute of Technology, Montgomery, W. Va. 5-yr. B.S. in Mng. on co-operative system in coal. Edward L. Holt, head, Dept. of Mng. and Geology.

University of Wisconsin, Madison, Wis. 4-yr. B.S. in: (1) *Mng. Eng., (2) *Met. Eng. Geo. J. Barker, chairman, Dept. of Mining and Metallurgy.

Yale University, New Haven, Conn. 4-yr. B. Eng. in *Met. Arthur Phillips, chairman, Dept. of Metallurgy.

CANADA

University of Alberta, Edmonton, Alta. 4-yr. B.Sc. in Mng. Eng., with options in: (1) Metal Mng., (2) Coal Mng., (3) Pet. Eng., (4) Eng. Geol. K. A. Clark, professor of metallurgy; E. O. Lilge, professor of ore dressing; T. H. Patching, asst. prof. of Mng. Eng.; J. W. Gregg, asst. prof. of Pet. Eng.

University of British Columbia, Vancouver, B. C. 4-yr. B. of Applied S. in: (1) Mng. Eng., (2) Met. Eng., (3) Geol. Eng. F. A. Forward, head, Dept. of Mining and Metallurgy; H. C. Gunning, head, Dept. of Geology and Geography.

Laval University, Quebec. 5-yr. B.A.Sc. in: (1) Mng. Eng., (2) Met., (3) Geol. Eng. G. Letendre, director, Dept. of Mining and Metallurgy.

McGill University, Montreal, P. Q. 5-yr. B. Eng. in: (1) Mng. Eng., (2) Met. Eng. J. J. O'Neill, dean of Engineering.

Ecole Polytechnique (Montreal University), Montreal, P. Q. 5-yr. B. Applied S. in: (1) Mng. Eng., (2) Mng. Geol., (3) Met. Eng. P. Mauffette, head, Dept. of Geology; L. Bourgoin, head, Dept. of Metallurgy; P. R. Riverin, head, Dept. of Mining.

Nova Scotia Technical College, Halifax, N. S. 5-yr. B. Eng. in Mng. Eng. A. E. Flynn, professor of mining engineering.

Queen's University, Kingston, Ont. 4-yr. B.S. in: (1) Mng. Eng., (2) Met. Eng., (3) Geol. Sciences. A. V. Corlett, head, Dept. of Mining Engineering; T. V. Lord, head, Dept. of Metallurgical Engineering; J. E. Hawley, head, Dept. of Geology.

University of Toronto, Toronto, Ont. 4-yr. B. Applied S.: (1) Mng. Eng., (2) Met. Eng., (3) Mng. Geol. R. E. Barrett, professor of mining engineering; L. M. Pidgeon, professor of metallurgical engineering; G. B. Langford, Dept. of Geological Sciences.

New Book A Must for Engineers

Readers have learned to expect something concrete and instructive from the pen of Dean Edward Steidle. His new book, *Mineral Industries Education,* is no disappointment to his old readers. The thesis of the book is set forth in the preface in these words, "We insist that man must be weaned from his egocentric thinking to consideration of what is best for the most, that he must desist from useless exploitation and destruction of man and nature for personal benefit and initiate a program of conservation, if he is to survive."

This book is in effect a combination and reprint of three former circulars from Pennsylvania State College: Circular 31, "Roots of Human Progress"; Circular 33, "A Philosophy of Conservation"; and Circular 35, "Wanted: Mineral Industries Colleges." These three circulars form the titles of the three parts of the new book.

Dean Steidle has presented a philosophical treatise dealing with man, his ethics and shortcomings; the degradation of our mineral resources and their necessity to our American standard of living. With depleting and lower grade mineral deposits the ingenuity of man and research are called on to offset nature's rich deposits which have been and are being exploited. Properly trained men are necessary to meet the challenge and these men must not be narrow technologists in a special field but well-trained personnel with humanitarian and economic background.

His philosophy can probably be summarized in the following basic considerations:

(1) The world and the public as a whole must be made more mineral conscious. (2) Educate the trained man. (3) Expand the knowledge of the fundamental properties of minerals. (4) Maintain the knowledge that common hazards must be met with a common front. (5) Achieve greater understanding through congresses, technical conferences, exchange professors, exchange students, technological aids; and aid in the training of skilled technicians.

The School of Mineral Industries of Pennsylvania State College has been established to train men for those ends. Dean Steidle gives the history and background of the School.

The book is recommended as a "must" for educators in the field of mineral technology. It also should be read by men in research and those to whom our heritage of minerals is invested. It is well written and recommended for general reading. It is profusely illustrated with woodcuts and diagrams. The front and back covers comprise a colored map showing the known sources of primary wealth, both mineral and nonmineral of the Commonwealth of Pennsylvania.—**Clyde Williams,** Director, Battelle Memorial Institute.

"Mineral Industries Education," by Edward Steidle, The Pennsylvania State College, Printed by The Carrolltown News, Carrolltown, Pennsylvania, 252 pages.

Truck Haulage Improved at Inspiration by Attention to Details

by TOM BILSON

TO recover the remaining ore tonnages along the south side of the Inspiration orebody, the company began open-pit operations in early 1948 in addition to underground mining.

Due to the differences in elevation between the orebody and the existing ore handling and treating plants, the truck haulage operation is uphill. Road grades were established at 7 pct maximum.

The maximum road grade of 7 pct was an important factor in deciding upon the size of truck and horsepower needed for this type of operation. The trucks chosen were twelve Darts, Model 250, all originally powered with Hercules DFXH Diesel engines. These engines have a maximum horsepower rating of 260 at 2100 rpm, but it was recommended by the Hercules Motor Corp. that longer engine life and better operating efficiency could be gained by reducing the engine speed to 1850 rpm. At this engine speed the horsepower rating is 240. At the present time a portion of the fleet is being converted to Model NHRS-600 Cummins engines with a rated horsepower of 300 at 2100 rpm. To date three trucks have been converted. Two of the Cummins engines are being used with a conventional clutch and transmission arrangement. In an effort to reduce shock loads in the rear axles, the horsepower of these two engines was reduced to 250. To date no increased rear axle trouble has been encountered in these two trucks and the engines perform satisfactorily at the reduced horsepower. The other Cummins engine is operating at its full rated horsepower in conjunction with a Twin Disc torque converter. The converter has a hydraulically actuated clutch which permits a direct drive feature. Inasmuch as the direct drive defeats the purpose of the converter, it is used in downhill or level operation when the truck is empty. The converter also has a braking feature which exerts a strong retarding action in downhill operation. The most important advantages of the converter are the lessening of shock loads on the rear axles and the elimination of engine lugging. Maximum governed engine speed is maintained constantly when the converter is operated in hydraulic drive. The most serious converter trouble encountered has been due to leaking seals on the hydraulic clutch and the hydraulic valves which actuate the clutch. It is planned to couple a converter with a conventional dry clutch for further reduction in maintenance work.

The trucks are equipped with Hiel dump bodies and Hiel three-section telescopic hoists mounted outside the frame members. The dump bodies were originally 14 cu yd but now have one-ft side boards added in order to accommodate 16 cu yd or a 23 ton pay load without excessive spillage along the haul roads or at the crusher. The trucks haul the average load of 23 tons up to 7 pct grade at a speed of 7 mph and average 1000 tons per truck-shift. The ore haul is seven tenths of a mile one way at present and will eventually be over a mile. Waste hauls average one half mile each way and are kept level where possible. An average speed of 22 mph is maintained in downhill and level operation.

The driving axles are Timken, Model 472, operating in tandem. They have a carrying capacity of 70,000 lb and are double reduction with an over-all ratio of 11.56 to 1. The rear axles have required more continuous maintenance than any other part of the truck. The first indication of mechanical failure is in the bearings at either end of the differential through-shaft. This in turn contributes to additional bearing failure and finally gear failure. Another problem has been to keep the differential carrier assembly from pulling away from the rear axle housing. The area of the mating surface between these two parts has been increased and additional cap screws and tapered pins have been used in an effort to hold the parts together more securely. This adaptation has lightened the problem a great deal but it has not been entirely eliminated.

The trucks are equipped with Vickers hydraulic steering boosters and air-assist clutch boosters which make for easier driving and less driver fatigue.

Tires are 14:00-24, 20-ply rock service, mounted on Budd wheels. The wheels are disc type with 10-hole hubs and have 10-in. flat rims. Tire pressures are maintained at 75 lb. Mileages average 17,262 without recapping. Recapped tires average 11,760 miles before recapping and 9844 miles after capping for a total of 21,604 miles. Since an average of 5502 original tire miles are sacrificed by recapping and an average of 4342 miles are gained by recapping, there is an average net loss of 1160 miles that could be recaptured by making use of all the original tire miles. Recapping has not been found to be economically practical at Inspiration. Only selected carcasses are capped and this is done with rubber conservation in mind rather than economy. One of the strongest contributing factors to good tire mileage is good road maintenance. Haul roads at Inspiration are maintained continuously with a Caterpillar #12 Motor Grader and are sprinkled with a 1000-gal tank truck.

At the present time, haulage operations are on three shifts, with eight operating truck-shifts on the day shift and four each on the afternoon and graveyard shifts. General truck operating statistics are as follows:

The trucks operate an average of 17½ hr per day with 4 hr being set aside for fueling, servicing, engine warmups and routine maintenance such as checking brakes, tires, differential covers, etc. The remaining 2½ hr are idle time due to lunch periods and shift changes.

After every 2½ shifts of operation the air cleaners are washed and changed; and the trucks are lubricated. Engine oil and filter elements are changed every 150 hr. Fuel consumption now averages 4.5 gal per hr, and make-up oil averages 1 pint per hr.

Through an oversight, the name of the author of the excellent article "Selecting Two-Way Radio Communication" which appeared in this feature last month was omitted. He was Mr. J. U. Larsen, general mine foreman, Phelps Dodge Corp., Morenci, Ariz. Our apologies to Mr. Larsen.

LINATEX

An extra-tough rubber is the answer to many maintenance problems.

TOUGH metal and tough rubber are needed to withstand the drubbing given conveyor belts, pipes, pumps, cones, chutes, and other equipment by fast-moving rock masses and abrasive sands.

Rubber has always proved itself a sturdy ally in the fight against destruction, and "Linatex," a peculiarly rugged type of rubber, has been particularly effective.

A British product, made only in the tropics, Linatex has never been publicized widely in the United States, chiefly because of apparent British reluctance to invest capital in American branch offices. Its initial introduction into this country in 1929 was given the quietus by the great depression, and a second attempt at the beginning of World War II was overshadowed by military needs.

Linatex has, however, made a highly favorable impression very close to home. The Canadian mining industry has been using it extensively in various crucial places where maintenance problems normally plague miners. In the United States, Tennessee Copper has found at least ten uses for Linatex, and is finding more continually.

The claims made for Linatex are impressive, and most of them have been proved in actual practice:

1) It will not perish under any climactic conditions
2) It can be joined by simple cold cement, and the joint thus made is rupture-proof
3) It does not harden at low temperatures
4) It is from three to four times more resilient than many rubbers
5) It is nonabsorbent
6) It has greater resilience to abrasion than any metal
7) It is light in weight—Sp. Gr. is 197
8) Vaseline, wax, alcohol and glycerine do not deteriorate Linatex
9) It is resistant to acids, except those of an organic nature
10) It is unaffected by sea water and a wide range of alkalis

Another noteworthy advantage, and one which has proved itself most popular with Linatex users, is the fact that it can be used to repair a worn part by merely cementing additional Linatex over the surface. The vulcanization process now being used to repair conveyor belts and other equipment items is thus avoided. One user found it to be "the best rubber material on the market for sticking to iron, to wood, or to itself . . . care and cleanliness are the main requisites." Linatex is easily shaped to fit various pieces such as pump parts—thus permitting on-the-job repairs, and eliminating the necessity for sending away to the manufacturer for parts. Such objects as pump runners can be restored easily to their original contour after wear. Theorizing on the subject of wear resistance, one mine manager created an intriguing visual conception of how Linatex works, when he said: ". . . one visualizes a surface whose miniature mountains bend before the oncoming stream of solids, and when the stream has passed they again assume their erect position. The elasticity or the power to return to the original position and the adhesive power of the individual mountain base in relation to the main body must be greater in Linatex than in most materials used as counterabrasives."

Application

Although Linatex is an extremely wear-resistant form of rubber, it will disintegrate rapidly under the repeated impact of heavy bodies such as coarse ore in chute linings unless it is sufficiently thick. It is now being made in sheets 1/32 to ½ in. thick, and when thicker protection is required, multiple sheets must be cemented together. A thickness of 3/16 in. was used on a conveyor belt which later handled over 51 million tons of material in a Canadian mill. The same thickness of high-tensile rubber, it might be added, wore out after only 12½ million tons. In lining trunnions in pebble mills, one operator has found ½-in. Linatex useful in replacing 1¼-in. castings. Another operator reported using ½-in. Linatex coverings on the wearing parts of ball mill spiral drum feeders. A year and a half later, the covering was renewed, and the operator reported "Indicated life (with minor patching)—indefinite." One organization reported the use of Linatex as a covering for cell division plates at its Mexican operations, and noted the "outstanding advantage" that Linatex "can be built up to any desired thickness to take care of more adverse wear on certain areas and severe wear at critical points."

In applying Linatex, the surfaces to be bonded must be thoroughly dried and, if possible, given several days in which to allow proper bonding to take place. One operator has been using infra-red lamps to dry the area around the breaks in conveyor belts before applying Linatex. This, of course, varies according to the nature of the material to which Linatex is to be glued. It is also necessary to protect the glued edges. Sands and other materials will wear out the glue and undercut the Linatex. Steel bars or plates have proved useful in protecting leading edges. Neat, effective, and workmanlike repairs can be effected where application of ordinary rubber would be difficult, if not impossible. When carefully applied, Linatex can be used in places where it is subject to a terrific beating, such as in cyclone separators. A Linatex-lined cyclone has been known to outlast several unlined steel plate cyclones. A Canadian mill superintendent summed up the versatility of Linatex when he said: ". . . the variety of uses to which it can be put is a challenge to one's ingenuity."—*from a 1951 Annual Meeting paper by John F. Myers.*

Metallurgical Applications of the DorrClone

by Frank T. Weems

The basic operating properties of the DorrClone are discussed and certain metallurgical applications which exploit these properties are presented. An effective method of controlling the consistency of the DorrClone underflow is described.

THIS paper presents in a general manner some of the applications of the DorrClone (Dutch States Mines cyclone) in the metallurgical and heavy chemical fields. Technical or mathematical analyses of the design factors and of the mechanism whereby the cyclone effects its separation have been capably treated in a series of previous papers.[1-4] Engineering and operational aspects of a few installations and laboratory tests have been chosen to emphasize the unique classification characteristics of the DorrClone and to illustrate its utility in certain difficult situations. Its use in coal washing and heavy-media operations are not considered.

Some 25 or more industrial installations and applications of the DorrClone in the metallurgical fields are operating at present, ranging from single trial units to complete batteries composed of a multiplicity of units. The data were obtained in part from some of these, and in part from operations of units at the Westport Mill, the laboratories and testing plant of the Dorr Co. at Westport, Conn.

The DorrClone was developed, in principle, by the research dept. of the State Mines, Limburg, Holland, during World War II. Its first use was to dewater a —50 micron sand used as a dense medium in coal washing. The metallurgical wet cyclone was first publicized by Driessen[5] and Yancey and Geer.[6] Since then the cyclone has been studied as a means of dewatering, heavy media concentration, and fine size classification.

The DorrClone is shown in Figs. 1 and 2. Pulp to be treated is pumped through the feed nozzle, A, into the feed cylinder, B. The feed nozzle is of rectangular cross-section, the outermost edge being tangent to the feed cylinder walls. Feed shims, C, may be attached to the innermost walls to adjust the open area of the feed nozzle available to entering pulp.

The tangential injection of feed under pressure supports the vortex action of the pulp that has been detained in the cyclone; the centrifugal forces of this vortex throw the coarse particles to the walls of the cone, D, where they collect and pass downward and out through the adjustable apex opening, E. The fine particles contained in most of the water that entered with the feed pulp move to the inner spiral of the vortex and flow out through the vortex finder, F, contained in the orifice plate, G, which forms the top of cyclone chamber. The overflow pulp may then spray freely into a spray chamber, H, surmounting the cyclone or pass directly into a 90° elbow, I, of somewhat larger diameter than the vortex finder.

Installation

Where more than one cyclone is to be installed, best overall efficiency and ease of control are obtained with equal distribution of both pulp volume and weight of solids among the cyclones, and with the same pressure being maintained at each cyclone feed nozzle. Fig. 3 is a suggested arrangement for feeding two or more cyclones in parallel.

Feed pressure control: Under normal operating conditions it is not unusual for some surge to exist in the feed that is to be sent to the cyclone. As will be discussed later, surges in the solids content of the pulp are usually not of great operational consequence, but surges in feed volume are a problem.

Several systems have been devised for absorbing surges in feed volume, each involving a surge tank. If the surges are small and fairly rhythmical, a tank of sufficient size might be installed to dampen out

F. T. WEEMS is Research Engineer at the Dorr Co., Westport, Conn.

Discussion on this paper, TP 3093B, may be sent to AIME before Sept. 28, 1951. Manuscript, Feb. 9, 1951. St. Louis Meeting, February 1951.

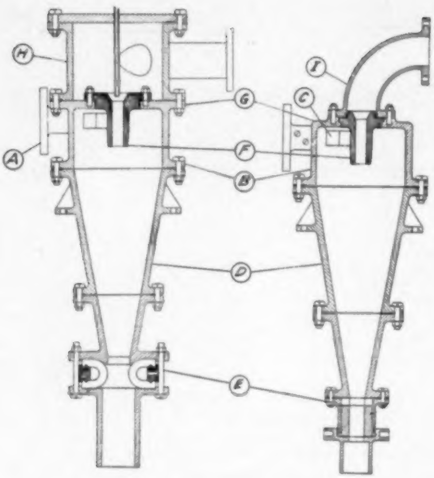


Fig. 1—The DorrClone.

A — Feed nozzle
B — Feed cylinder
C — Feed shims
D — Cone
E — Adjustable apex opening
F — Vortex finder
G — Orifice plate
H — Spray chamber
I — Elbow

the surge. If the surges are large or of long period, the pump speed should be changed by some control or regulator system,[7] and the number of cyclones on the line should be varied to keep the inlet pressure relatively close to the optimum value. For conditions between these two extremes, one of two methods might be used: 1—install pumps of slightly greater capacity than required for the maximum surge and then add water to keep a constant level in the feed tank, or 2—recycle overflow as shown in Fig. 4. Where a clean underflow is the prime requisite, method 1 is recommended; for maximum recovery of solids in the underflow, method 2.

DorrClone Underflow Control

If full advantage is to be taken of the ability of the DorrClone to produce a dense underflow, some method must be adopted whereby physical adjustments of the cyclone are made automatically in response to the normal operating variations in feed composition. The density of the underflow from the cyclone has been shown to be a function of the apex orifice diameter if the feed rate and analysis are fixed[2, 3, 4, 5, 6]; and, as a corollary, the density of the underflow may be controlled by adjusting the apex orifice opening as the feed rate and composition vary. By decreasing the apex orifice opening, the density of the underflow is increased.

The adjustment of the apex orifice to control underflow density should be made in a manner that will minimize disturbance of the normal flow pattern of the cyclone. The most convenient device now known is an adjustable aperture.

There are two types of restricted apertures that have been used with good results: 1—A rubber doughnut that may be compressed mechanically to close its inner diameter, shown in Fig. 1. 2—A rubber tire that may be inflated to close its inner diameter. Another type of closure consists of a cone that can be inserted or withdrawn from a fixed apex opening to decrease or increase the area available for pulp discharge. This gives underflows of somewhat lower density.

It has been found experimentally that a vacuum exists in the core of an operating cyclone. The magnitude of this vacuum varies with the consistency of the underflow pulp, other operating factors being fixed. The absolute value of the vacuum corresponding to some given underflow consistency will be a function of such factors as feed pressure, physical dimensions of the component parts of the DorrClone, length and size of the overflow pipe, etc. However, having a cyclone operating under conditions of normal variations, the vacuum in the air core of the cyclone can be correlated with the density of the cyclone underflow. In the region of underflow densities commonly desired, this vacuum will change from a few inches to several feet of water vacuum as the underflow density changes only a small percentage. This vacuum has been used effectively as the intelligence in controlling the consistency of the DorrClone underflow.

Work on the automatic control system, based on vacuum, was initiated by Weaver and Wright of the American Cyanamid Co. and subsequently developed in its present aspects, see Fig. 5, by Fitch of the Dorr Co.

The DorrClone can be equipped with any type of sensitive nonhunting control instrument capable of operating in response to a 0 to 10 or 0 to 20 in. of water control range. It is preferable to have manual adjustment for both proportional band and reset time. The intelligence is applied to this instrument, the output of which normally operates a pressure booster. A 100-psi compressor is connected through this booster to the apex valve, thereby allowing the pressure in the apex valve to be varied between zero and about 85 or 90 psi in response to changes in output pressure of the controller. The vacuum at the probe, therefore, controls the pressure in the apex valve. This pressure determines the size of the apex orifice, which in turn controls the density of the underflow.

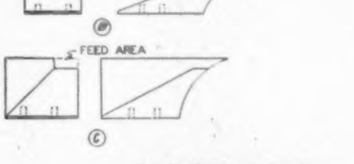


Fig. 2—Details of DorrClone.

A — Section through feed nozzle
B — Small shim
C — Large shim
D — Detail of tire-type apex valve

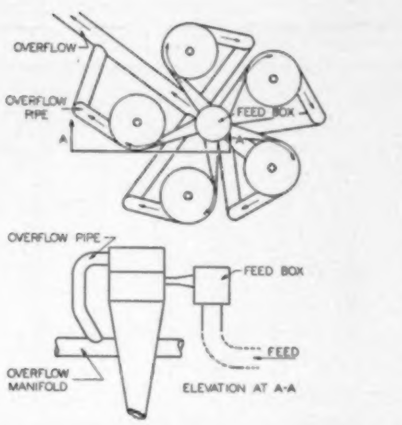


Fig. 3—Multiple DorrClones feed and overflow assembly.

The average consistency of the underflow is set by adjusting the control point of the instrument. Response of the instrument to changes in vacuum is practically instantaneous. The magnitude of the response to a given change in vacuum, however, can be controlled by setting the proportional band and reset time. These adjustments should be balanced to give the closest possible control without the risk of hunting.

As an example, the control is set for 6 in. of water vacuum, corresponding to an underflow density of 72 pct solids and an apex valve pressure of 75 psi. If the feed pulp becomes more heavily loaded with coarse material that reports to the underflow, the underflow volume (hence density) will increase and the probe vacuum will tend to increase to maybe 10 in. vacuum. The control instrument's output will decrease the apex valve pressure, allowing the orifice to open. As the valve opens, the probe vacuum decreases until equilibrium is re-established at 6 in. vacuum. The density of the underflow will again be about 72 pct solids.

By having this instantaneous positive control action, plugging of the underflow by normal changes in feed density is virtually impossible.

A 24-in. DorrClone to be used in desliming Florida phosphate rock at the Homeland Mine of Virginia Carolina Chemical Co. was equipped with the vacuum-type underflow density control system. Details of testing arrangement are given later.

The vacuum developed in the cyclone was taken by a ¼-in. probe extending into the vortex finder to a Foxboro Model 40 Stabilog controller. The controller operated through a 3 to 1 pressure booster to adjust the pressure in a tire-type apex valve.

When using this method of underflow consistency control, the recovery of valuables as well as the density of the underflow show little change with rather large changes in solids content of the feed. The results of a 7-hr test with samples taken at 30-min intervals are shown in Table I and are plotted in Fig. 6. There are rapid fluctuations of the feed between 29.1 pct and 46.0 pct—200 mesh, 7.8 pct and 21.4 pct solids, and equally rapid variations in the overflow between 2.9 pct and 10.1 pct solids. The rake product varied only between 66.7 pct and 72.8 pct solids, the recovery of +150 mesh material varied between 97.9 pct and 99.4 pct recovery in the underflow, and the elimination of slimes varied between 84.1 pct and 86.5 pct of the slimes that entered with the feed reporting to the overflow.

In Fig. 6 it is shown that the underflow density can be held constant within the control limits of ±3 pct, independent of the per cent solids in the feed. The small changes in per cent solids of the underflow do not seem from this plot to be related to either feed or overflow density. Through this control of underflow density, the elimination of slimes and recovery of valuable material are held at a constant high value, as shown in Fig. 6, in spite of the large rapid changes in feed and overflow consistency.

Applications and Limitations

The mechanism whereby the cyclone makes its separation is generally considered as the settling of discrete particles under the influence of centrifugal force. The high shearing stresses in the cyclone tend to break up and prevent the reformation of any flocs that exist in the pulp. At the same time, the high centrifugal forces acting on the particles suspended in the pulp will give sufficient force to even the extremely small particles to enable them to exceed the yield point of the pulp and settle through it. Following are mechanical features of the unit: 1—The elimination of flocs through shearing forces, 2—the increase in the acceleration with which particles act against the restraining force (yield strength) of the pulp, and 3—the reduction of effective viscosity through increased rate of shear. These features enable classification in the cyclone free from the undesirable effects of flocculation, even without dilution or the addition of chemical dispersing agents. This makes the cyclone especially attractive for fine separation with pulps that are naturally flocculent.

The cyclone has produced separations in which the top size of the fine product range from 10 to 150 microns; the exact separation being a strong function of the specific gravity of the solids and the plasticity of the pulp. In any given case the cyclone will not require nearly as much dilution water to achieve the fineness of separation as a hydroseparator. In addition, the underflow from the cyclone may be delivered to the process at only slightly lower per cent solids than the rake product from a classifier and at much higher per cent solids than the normal hydroseparator underflow, even when operating on a thoroughly dispersed pulp. This makes the cyclone useful for desliming ahead

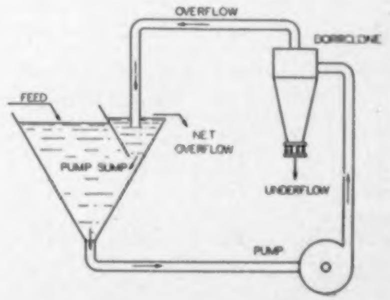


Fig. 4—A suggested feed arrangement.

Table I—Time Samples from Homeland Cyclone

Control Feed Pressure, 14 Psi—Cyclone, 24 In., 20°—Vortex Finder, 6 In.—Feed Entrance, 20 Sq In.—Apex, Rubber Restricted

	Feed				Underflow				Overflow				Recovery, Pct	Recovery, Pct	Removal, Pct
	−200	Solids, Pct	Tons Per Hr	Gal Per Min	−200	Solids, Pct	Per Hr Tons	Per Min Gal	−200	Solids, Pct	Tons Per Hr	Gal Per Min	+200	+150	−200
9:00 am	45.8	20.4	49.3	785	5.6	71.4	27.3	93	95.7	10.1	22.0	692	96.4	99.1	93.2
9:30	37.2	16.2	29.8	776	5.0	71.0	19.3	66	91.2	6.3	10.5	710	96.0	99.4	96.5
10:00	40.0	13.5	27.0	796	5.3	68.1	16.9	62	97.8	4.5	10.1	736	98.6	99.0	91.8
10:30	46.0	16.7	28.2	792	12.0	68.5	17.1	62	98.5	6.9	11.1	728	98.9	99.4	84.1
11:00	40.0	15.5	36.5	822	8.8	68.3	23.6	86	97.4	7.1	12.9	736	98.5	99.2	85.8
11:30	35.0	18.5	37.5	802	4.7	72.0	25.1	83	95.7	6.9	12.4	719	97.8	99.3	91.0
12:00 n	41.6	11.0	27.9	790	5.4	67.9	16.8	62	96.5	5.4	11.1	728	97.6	98.9	92.2
12:30	40.9	11.6	22.5	805	7.4	69.5	14.2	51	98.4	4.4	8.3	754	99.0	99.5	88.5
1:00	43.8	15.0	38.8	778	6.1	71.3	22.7	77	97.2	7.5	16.1	701	97.9	99.2	91.9
1:30	47.1	11.2	23.2	788	10.2	66.7	13.5	52	98.3	5.1	9.7	736	98.6	99.0	87.4
2:00	32.2	16.9	39.9	792	4.0	72.8	27.6	91	95.4	6.9	12.3	701	99.3	97.9	91.5
2:30	29.1	21.4	45.3	778	3.9	72.5	32.0	105	89.8	7.5	13.3	673	95.6	98.2	90.6
3:00	42.4	7.8	19.2	817	4.2	72.7	11.4	37	98.6	2.9	7.8	780	99.0	99.2	94.1
3:30	25.9	18.7	36.6	787	2.1	72.1	26.3	87	87.1	6.3	10.3	700	95.1	97.9	94.3
4:00	36.9	9.0	23.8	801	3.1	72.0	15.3	51	97.1	3.7	8.5	750	98.3	99.0	94.6

Table II—Wear Comparison of Construction Materials

Material	Thickness, In.	Life
Mild steel	1/4	125 to 140 hr
Hard alloy steel, (350 Bhn)	1/4	6 to 8 weeks
Neoprene	3/8	8+ weeks
Gum rubber	3/8	in use since March 1950, no wear

of flotation, where a high density conditioning is essential.

Because of the mechanical features of the separation occurring in the DorrClone, clear overflows of the type commonly associated with good thickener practice cannot be made. True thickening requires a *line settling* of the pulp bed to expose a clear supernatant. All small particles are collected from the supernatant by the dense descending blanket of flocculent slimes, and large particles are sustained by the yield strength of the blanket. The net result is that all particle sizes settle together, with essentially no classification, in a thickener after the initial sedimentation of the coarsest particles at the feed well. Even at the feed well this sedimentation is restricted to those particles that are heavy enough to overcome the yield strength of the pulp. In a cyclone, even the small particles possess enough centrifugal force to exceed the yield strength of the pulp, and mechanical dispersion eliminates the col-

Table III—Typical Results from Sydney Cyclones

Control Feed Pressure, 18 Psi—Cyclone, 48 In., 20°—Vortex Finder, 8 In.—Feed Area, 40 Sq In.—Apex, Needle-type

TEST	1	2	3	4	5	6	7	Avg
Feed								
Solids, pct	8.4	19.4	15.4	19.8	23.0	21.4	32.6	20.0
Mesh, pct								
+20	0.0	1.6	0.6	5.2	1.8	4.3	3.8	2.5
+28	1.3	3.4	1.9	9.0	3.9	8.1	8.7	5.2
+35	2.6	8.3	5.9	16.8	11.7	16.9	18.5	11.5
+48	4.8	17.0	15.3	28.6	25.6	29.7	32.9	22.0
+65	12.6	31.1	32.3	42.8	41.1	46.3	51.5	36.8
+100	24.2	53.3	50.5	66.8	66.6	70.2	76.0	58.3
+150	34.1	60.2	60.1	71.4	72.4	76.7	82.3	65.5
+200	37.5	63.4	64.1	73.4	75.2	79.3	85.4	68.3
−200	62.5	36.6	35.9	26.6	24.8	20.7	14.6	31.7
Overflow								
Solids, pct	7.1	7.2	6.1	6.4	7.3	5.7	5.7	6.5
Mesh, pct								
+35	0.0	0.0	0.1	0.1	0.6	0.1	0.4	0.2
+48	0.0	0.1	0.2	0.2	1.6	0.2	0.7	0.4
+65	0.0	0.2	0.5	1.0	3.8	0.3	1.6	1.1
+100	0.1	0.7	1.0	4.9	7.9	0.5	3.7	2.7
+150	0.2	1.2	1.3	6.1	9.5	0.8	4.7	3.4
+200	0.4	2.0	1.9	7.3	10.9	0.9	5.6	4.1
−200	99.6	98.0	98.1	92.7	89.1	99.1	94.4	95.9
Underflow								
Solids, pct	23.0	52.4	44.2	54.6	63.2		50.0	47.8
Mesh, pct					2.6			
+20	1.7	6.1	4.0	4.0	5.9	3.0	5.9	3.9
+28	4.1	11.9	7.8	8.3		6.3	11.6	8.6
+35	8.9	20.4	14.1	15.6	13.4	13.1	20.5	15.1
+48	17.9	31.9	26.0	28.4	28.7	25.5	32.0	27.2
+65	35.2	50.7	48.0	47.3	48.3	49.7	48.4	46.7
+100	63.6	77.5	74.1	81.5	81.9	83.0	78.7	77.4
+150	74.5	85.5	83.1	88.1	88.1	90.5	87.1	85.3
+200	80.5	90.2	88.7	92.0	91.3	94.8	92.0	89.8
−200	19.5	9.8	11.3	8.0	8.7	5.2	8.0	10.2
Weight, recovery	0.463	0.686	0.717	0.78	0.80	0.834	0.924	0.745
+200 recovery	99.2	99.2	99.2	97.7	97.2	99.8	99.5	98.9
−200 elimination	85.6	81.5	77.5	76.7	71.8	79.3	49.2	74.5
Corrected to 71 pct underflow solids								
−200 elimination		88.5	89.2	85.8	77.2		77.1	83.5
Weight, recovery		0.67	0.674	0.76	0.79		0.889	0.755

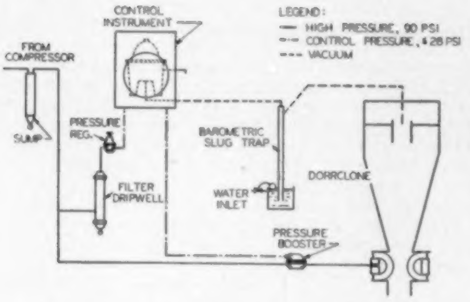


Fig. 5—Schematic of underflow density controller.

lecting together of slimes as flocs. Since the cyclone is always subject to classification instead of thickening, clear overflows cannot be produced with feed containing a natural full range of particle sizes. However, a clear overflow could be produced if the feed to the cyclone had been thoroughly deslimed in a previous operation so that there were no particles finer than the top size of the natural separation of the particular cyclone. Examples where overflows containing essentially no solids might result are: 1—Dewatering a concentrate in a cyclone operating so as to produce a top size of 20 microns if the flotation feed had been deslimed at 325 mesh or coarser. 2—Dewatering a pulp made up from a material, perhaps agricultural, which has a natural minimum grain size larger than the top size of the separation that would be made in the cyclone.

In the applications of the DorrClone discussed in this paper, data from field installations have been given, in some instances, while in others the data are from the laboratory.

Desliming

The DorrClone is especially applicable to desliming. The mechanical dispersion of the pulp eliminates settling of flocs (thickening) into the underflow. The dense underflows produced by the cyclone minimize the void volume in the underflow, thereby eliminating a maximum amount of the slimes that would be present in the pulp filling this voids volume. These two factors contribute to improved slime removals. The effect of centrifugal force to aid the small particles in exceeding the yield strength of the plastic pulp will allow high recovery of valuables without dilution of feed pulp. It was the combination of these factors that made possible the 91.7 pct slimes elimination and 97.5 pct recovery of valuables previously listed.

Where still more complete desliming is required, the DorrClone underflow may be repulped with water and fed to a second stage.

Florida Pebble Rock Phosphate

Details of American Cyanamid's Sydney units are given in a recent article by Crago.[1] The feed to the cyclones is washer debris at 14 to 17 pct solids and 35 to 45 pct —150 mesh. This is pumped from the surge tank at a rate of 9000 to 9500 gpm to a feed manifold. Pinch valves contained in 8-in. lines led to each of ten cyclones.

The feed entrance to the cyclone is 4 in. wide x 10 in. high. The vortex finder is 8 in. diam and the maximum apex opening is 5½ in. The overflow is removed to slime settling areas without further treatment. The underflow drops at 50 to 60 pct solids

Table IV. Typical Results from Homeland Cyclones

Control Feed Pressure, 14 Psi—Cyclone, 24 In. 20°—Vortex Finder, 6 In.—Feed Entrance, 20 Sq In.—Apex, Rubber Restricted

	1	2	3	4	5
Feed					
Solids, pct	14.2	23.1	25.5	20.2	14.2
Mesh, pct					
+20	1.7	2.1	3.5	2.2	2.3
+28	4.2	6.0	10.4	6.6	5.8
+35	8.4	15.7	17.6	15.1	11.4
+48	17.7	41.1	30.8	35.1	22.6
+65	33.7	64.4	48.3	56.9	39.9
+100	47.2	77.5	59.1	71.9	53.0
+150	54.5	80.6	65.4	75.5	60.2
+200	59.9	81.7	70.1	77.1	66.1
—200	40.1	18.3	29.9	22.9	33.9
Tons per hr (dry)	32.8	36.9	25.5	41.4	33.8
Overflow					
Solids, pct	6.5	5.8	4.4	5.1	5.5
Mesh, pct					
+35	0.0	0.73	0.3	0.35	0.18
+48	0.0	1.6	0.7	0.56	0.45
+65	0.26	4.8	1.1	0.96	0.89
+100	0.70	12.3	1.9	2.6	1.09
+150	1.6	17.6	4.0	5.0	3.11
+200	4.5	21.9	6.9	8.1	6.38
—200	95.5	78.1	93.1	91.9	93.62
Tons per hr (dry)	20.5	28.5	18.3	31.8	22.7
Underflow					
Solids, pct	70.2	69.8	71.7	76.6	72.8
Mesh, pct					
+20	6.0	3.8	7.1	4.8	8.2
+28	12.5	10.1	14.5	12.3	16.3
+35	21.3	23.0	24.5	24.5	26.4
+48	37.6	55.1	42.6	50.3	43.1
+65	60.7	81.4	67.0	76.2	65.6
+100	77.9	94.4	81.6	93.6	81.9
+150	86.9	97.4	90.3	97.2	89.5
+200	93.1	98.0	95.0	98.0	95.3
—200	6.9	2.0	4.97	2.0	4.7
Tons per hr (dry)	12.3	8.4	7.2	9.6	11.1
Weight, recovery	0.625	0.772	0.717	0.767	0.672
+200 recovery	97.1	93.9	97.2	97.5	96.8
+150 recovery	98.9	95.2	98.3	98.5	98.2
—200 removal	80.3	97.1	88.1	93.2	90.6
Feed, gal per min	794	721	765	770	742
Overflow, gal per min	723	670	702	684	675
Underflow, gal per min	71	51	63	86	67

Table V. Laboratory Tests for Desliming an Iron Ore

Test No.	1	2	3	4	5	6	7	Avg
Cyclone, in. diam	6	6	6	6	6	6	6	6
Feed entrance, sq in.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Vortex finder, in. diam	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Apex, in. diam	0.59	0.68	0.56	0.68	0.59	0.78	0.75	
Pressure, psi	35	35	35	35	35	35	35	35
Feed, pct solids	24	23.6	20.7	21.0	21.4	29.0	24.8	23.5
Overflow, pct solids	2.05	2.06	2.7	2.5	1.61	1.44	1.09	1.93
Underflow, pct solids	75	69.1	77.5	67.3	75.3	60.0	60.4	69.2
Weight underflow: weight feed	0.941	0.943	0.900	0.910	0.946	0.978	0.972	0.941
Feed, gal per min	56.6	55.6	49.5	49.1	54.5	50.0	47.3	51.8
Overflow, gal per min	47.1	45.1	43.1	41.1	46.6	33.2	34.3	41.5
Underflow, gal per min	9.5	10.5	6.4	8.0	7.9	16.8	13.0	10.3
Solids, sp gr	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2

Table VI. Results of Laboratory Tests for Desliming a Magnesite Ore

Test No.	1	2	3	4	5	6	7
Cyclone, in. diam	3	3	3	3	3	3	3
Feed entrance, sq in.	0.19	0.19	0.19	0.19	0.30	0.30	0.30
Vortex finder, in. diam	0.49	0.49	0.49	0.49	0.62	0.62	0.62
Apex, in. diam	7/16	7/16	7/16	7/16	3/8	3/8	3/8
Pressure, psi	10	20	40	60	15	30	60
Feed, pct solids	28.1	28.2	30.6	31.1	30.7	31.2	31.8
Overflow, pct solids	5.78	4.47	4.21	4.16	7.24	5.96	5.35
Underflow, pct solids	71.2	72.7	75.7	75.5	75.8	77.5	79.0
Weight underflow: weight feed	0.866	0.896	0.914	0.917	0.847	0.875	0.891
Feed, gal per min	10.1	11.7	15.2	19.3	15.9	22.0	30.4
Overflow, gal per min	7.8	9.1	11.6	14.7	12.6	17.3	23.7
Underflow, gal per min	2.3	2.6	3.6	4.6	3.3	4.7	6.7
Solids, sp gr	2.8	2.8	2.8	2.8	2.8	2.8	2.8

into a collection launder leading to a surge tank from which the sizer feed is withdrawn to a 12-ft quadruplex HX rake classifier.

The intelligence for the control of underflow density is the vacuum drawn at the top of the cyclone. This is relayed in this case through a Republic constant pressure regulator (Model P65S-AS 5714), which is integral with the cyclone. The control applies pressure at 35 psi to a piston that opens or closes the throttle valve into the apex of the cone. The total throw of this piston is 6 in., giving an opening of 0 to 100 pct of the apex area. This type of controller uses about 2 cfm (STP) of air per unit from a supply that may be 40 to 100 psi.

The DorrClone is subject to extreme wear at a point just above the apex valve. This wear is caused by the granular underflow pulp traveling at relatively high velocity. Of the several materials of construction used to withstand this wear, gum rubber has been by far the most satisfactory, as Table II shows.

A series of 24-hr tests were made on the Sydney installation. The results of these tests are reported in Table III. From the averages for these tests, it is seen that with a feed of 20 pct solids, 31.7 pct —200 mesh, 74.5 pct of the feed was recovered at 47.8 pct solids and containing 98.9 pct of the valuables and 25.5 pct of the slimes present in the feed. If the cyclone had been operated at 71 pct solids (common for the restricted aperture type valve), this slimes content would have been lowered to 16.5 pct of that present in the feed without affecting the recovery of valuables. Table III shows how the cyclone will accept feeds of widely varying composition and yield a consistent product and recovery. Each test has been recalculated for the underflow that would have been obtained with the standard DorrClone apex valve, the loss in weight recovery is purely at the expense of undesirable slimes, the valuables recovery would be unchanged.

Homeland Test

A 24-in. DorrClone unit was installed at the Homeland mine of the Virginia-Carolina Chemical Co. to deslime a —14 mesh phosphate rock ahead of flotation. The feed was taken directly from the washer distributor box, and there was therefore no chance for equalization of the per cent solids in the feed pulp ahead of the cyclone.

An 8x6 in. sand pump was driven at 1000 rpm by a 40-hp, 1750-rpm motor. The discharge of this pump was throttled by a 6-in. pinch valve, then fed

Table VII. Dewatering Mine Fill with a 24-In. DorrClone, Howe Sound Co.

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pressure, psi	34	33	32	40	39	38	37	40	38	37	30	29	28	27	35	34	33	32
Vortex finder, in. diam	2½	2½	2½	2½	2½	2½	2½	2½	2½	3	2½	2½	2½	2½	2½	2½	2½	2½
Feed area, sq in.	3.5	4.75	7.5	2.0	3.5	4.75	7.5	2	4.75	4.75	2.0	3.5	4.75	7.5	2.0	3.5	4.75	7.5
Feed																		
Solids, pct	42.3	44.2	44.8	46.6	43.1	45.6	47.8	44.5	44.7	45.5	44.3	46.1	44.7	45.5	45.1	45.8	45.5	44.7
Mesh, pct																		
+65	7.0	10.6	7.7	10.8	4.7	12.0	9.8	5.5	4.5	6.9	3.4	5.2	5.8	4.4	6.2	7.3	5.4	7.0
+100	21.1	25.1	22.0	25.6	16.2	26.8	25.3	19.5	17.1	21.7	17.6	20.4	21.2	18.2	20.7	22.3	20.3	23.1
+200	52.7	53.5	52.0	54.5	47.9	56.4	56.2	54.5	50.2	54.2	55.2	57.9	58.3	56.7	57.9	57.5	58.6	59.4
+325	69.6	68.8	67.4	69.4	60.4	71.0	71.4	70.2	67.1	70.4	72.4	73.1	72.9	72.8	73.3	73.2	73.2	73.7
−325	30.4	31.2	32.6	30.6	39.6	29.0	28.6	29.8	32.9	29.6	27.6	26.9	27.3	27.2	26.7	26.8	26.8	26.3
Tons per hr	41	45	53	39	43	47	55	39	47	47	33	38	42	50	36	41	45	53
Gal per min	286	299	341	238	286	295	324	254	303	301	216	234	270	315	229	256	284	342
Overflow																		
Solids, pct	20.5	17.3	22.3	22.0	18.1	14.7	19.7	13.9	14.7	19.6	21.0	20.8	14.5	13.2	18.6	16.6	16.3	12.9
Mesh, pct																		
+65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0
+100	0.7	0.3	0.8	0.5	0.2	0.1	0.4	0.2	0.2	0.5	0.7	1.1	0.3	1.1	2.0	0.7	0.7	0.2
+200	12.7	5.1	12.5	12.5	5.1	3.0	6.4	3.0	2.7	10.0	12.7	17.0	6.2	15.9	15.5	10.3	9.7	5.0
+325	30.6	17.3	29.2	30.8	18.2	11.8	17.8	11.5	10.6	28.8	31.4	34.2	18.1	33.1	30.2	27.7	23.1	15.0
−325	69.4	82.7	70.8	69.2	81.8	88.2	82.2	88.5	89.6	71.2	68.6	65.8	82.9	66.9	69.8	72.3	76.9	85.0
Tons per hr	30.2	36.6	39.7	30.3	34.4	40.5	47.4	34.0	40.2	38	25.6	30.4	36.4	41.0	33.1	34.7	38.4	47.0
Underflow																		
Solids, pct	67.5	69.1	67.9	69	68	68.8	69.0	66.4	66.7	66.6	68.4	66.7	68.9	66.6	66.3	67.3	65.3	66.1
Mesh, pct																		
+65	8.4	11.7	9.6	13.5	5.7	14.3	11.0	6.1	5.2	8.3	4.3	6.5	6.1	5.1	10.0	9.1	6.0	8.0
+100	25.7	26.2	28.4	32.2	20.2	31.3	28.4	23.2	19.7	26.2	19.3	24.3	22.4	21.9	28.4	26.4	23.3	26.0
+200	62.5	61.9	64.6	66.8	58.9	63.8	63.6	63.9	58.5	65.3	63.7	66.6	63.8	65.2	68.7	66.3	65.4	65.9
+325	78.6	78.2	79.7	81.3	77.9	79.4	79.3	80.0	77.1	81.9	80.0	81.4	79.8	81.4	83.3	84.0	80.5	80.3
−325	21.4	21.8	20.3	18.7	22.1	20.6	20.7	20.0	22.9	18.1	20.0	18.6	20.2	18.6	16.7	16.0	19.5	19.7
Tons per hr	10.8	8.4	13.3	8.7	8.6	6.5	7.6	5.0	6.8	9.0	7.4	7.6	5.6	9.0	2.9	6.3	6.6	5.0
Recovery	74.1	81.4	74.9	77.7	80.0	88.0	86.1	87	85.6	80.8	77.5	79.8	86.7	82.0	92.0	84.6	85.5	88.5
Separation, microns	132	107	130	126	103	81	114	93	90	123	131	142	111	142	154	129	128	104

through 6 ft of straight pipe to an adapter into which a pressure gage was tapped. The feed nozzle had a maximum opening of 8x3¾ in. Feed shims could be bolted into this nozzle to produce smaller open areas. Vortex finders of 5, 6, 8, and 10 in. diam were available; the 6-in. is the only one thoroughly tested to date. The overflow line was 10 in. at the spray chamber, reduced to 8 in. at the elbow. The 8-in. pipe ran off at 45° to a measuring box and then to disposal. The apex valve had a 4-in. maximum opening and was controlled automatically. The rate of discharge through this valve was measured by tilting a launder to collect the full flow for a timed interval in a weighing drum.

Over a period of three weeks five tests were made on this DorrClone by the Lakeland, Fla., laboratory of the Minerals Separation North American Corp. A summary of results is reported in Table IV. Tests 1, 3, and 5 were made with one dragline operating at three different positions in one mining area, Tests 2 and 4 with another dragline at two different positions in a mining area several miles away from the first. Therefore, in these tests, the characteristics of the feed were not only changing within any given test (the data of Table I were collected during Test No. 1 of Table IV), but the nature of the matrix was completely different from test to test. With the wide variation of average feed conditions 14.1 pct to 25.5 pct solids, 25.5 pct to 41.4 pct —200 mesh, the average underflow was not lower than 69.8 pct and was as high as 76.6 pct solids with a 97.5 pct recovery of valuables and 91.7 pct elimination of slimes. This was accomplished while rejecting the slimes at 4.4 pct to 6.5 pct solids. As a comparison, the hydroseparator at Homeland must not exceed 1.5 pct solids in the overflow or the losses of +150 mesh become excessive. Thus, the amount of water going to slimes settling when using a DorrClone is only 23 pct to 33 pct of that resulting from the hydroseparator.

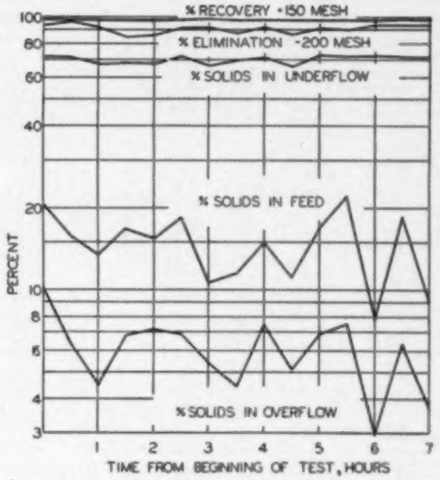


Fig. 6—Plot of Homeland data on desliming phosphate rock.

Iron Ore

Laboratory studies were made for desliming with a DorrClone ahead of flotation. A few tests, reported in Table V, were taken at random from one phase of this work. The results of flotation tests made on these products by the Mineral Dressing Laboratory of American Cyanamid showed good recoveries of iron, 89 to 94 pct, with a high grade concentrate, 59 to 62 pct Fe, 7.6 to 10 pct SiO_2.

From Table V, the 6-in. DorrClone, which had a 0.75 sq in. feed nozzle and a 1-in. vortex finder, operated at 35 psi feed pressure. It deslimed an

Table VIII. Typical Results at Plant X on Pyrite Concentrates

Test No.	1	2	3	4	5	6	7	9	10
Pressure, psi	11.5	11.5	11.0	11.0	11.0	12.0	8.0	15.5	19.25
Vortex finder, in. diam	1.375	1.375	1.375	1.375	1.375	1.375	1.375	1.05	1.05
Feed area, sq in.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Feed									
Solids, pct	20.2	23.8	14.5	6.14	14.5	22.78	18.0	20.7	20.1
Mesh, pct									
+48	0.4	1.6	0.0	0.4	0.4	0.4	0.4	0.4	0.4
+65	3.8	10.6	3.0	2.0	3.2	3.2	5.6	3.4	3.4
+100	17.2	25.0	11.5	7.2	10.6	16.8	20.2	16.4	15.8
+150	38.8	42.8	18.5	18.0	72.4	36.6	37.6	35.2	34.0
+200	61.2	57.0	42.5	30.0	42.2	51.6	59.6	50.0	49.2
−200	38.8	43.0	57.5	70.0	57.8	48.4	40.4	50.0	50.8
Tons per day (dry)	37.1	49.8	29.4	16.7	27.5	61.1	28.5	46.8	44.4
Pulp, gal per min	25.8	37.5	27.7	35.0	35.0	40.5	24.5	32.1	32.3
Overflow									
Solids, pct	2.8	5.0	3.71	2.20	3.37	5.33	2.90	3.98	3.03
Mesh, pct									
+48									
+65									
+100	0.0	0.4	0.0	0.3	2.0	0.30	1.4	0.2	0.13
+150	0.8	0.5	0.5	0.8	3.2	0.35	2.8	0.3	0.33
+200	1.6	1.7	1.0	0.9	5.2	2.10	3.5	1.25	0.73
+300	3.2	4.1	3.0	2.9	7.2	5.30	5.6	3.65	2.83
−300	96.8	95.9	97.0	97.1	92.8	94.70	94.4	96.35	97.17
Tons per day (dry)	3.9	7.5	6.4	6.5	5.2	10.7	3.6	6.85	5.37
Gal per min	22.8	33.4	25.5	33.8	32.5	35.7	21.4	28.2	28.6
Underflow									
Solids, pct	76.6	74.0	74.8	66.8	69.7	74.9	67.7	74.4	75.2
Mesh, pct									
+48	0.4	2.0	0.2	0.2	1.0	0.4	0.4	0.4	0.6
+65	4.4	12.2	4.2	2.0	4.4	4.0	5.4	3.8	4.4
+100	19.6	28.4	16.4	8.0	18.0	21.0	20.4	18.8	19.4
+150	36.2	41.2	32.0	22.4	39.4	44.6	41.2	41.2	40.6
+200	69.6	65.6	60.2	45.2	56.0	61.6	65.6	38.6	57.6
−200	30.4	34.4	39.8	54.8	44.0	38.4	34.4	41.4	42.4
Tons per day (dry)	33.2	42.3	23.0	10.2	22.1	50.4	24.9	39.95	39.0
Gal per min	3.0	4.13	2.2	1.25	2.47	4.81	2.96	3.87	3.7
Recovery, pct	89.4	84.9	78.2	61.2	80.7	82.5	87.4	85.4	87.9

Table IX. Typical Results at Plant Y on Zinc Tailings, 3-In. DorrClone

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feed pressure, psi	19	49	49	20	50	50	51	51	49	50	50	19.8	19.8	34.5	34.5	50.5
Vortex finder, in. diam	1.375	1.375	1.375	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0.813	0.813	1.04	1.04	1.04	1.04
Feed area, sq in.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.50	0.50	0.50	0.50	0.50
Feed																
Solids, pct	16.1	22.2	22.0	22.4	15.5	17.6	21.3	18.8	14.4	19.4	16.1	19.9	22.5	13.1	18.7	15.1
Mesh, pct																
+48	2.0	7.8	9.2	6.8	1.0	1.8	5.4	3.6	1.6	5.8	1.2	3.8	8.8	1.0	2.4	1.0
+65	7.6	17.8	9.2	18.2	5.6	7.6	16.4	12.0	4.8	14.8	5.8	14.2	21.2	5.2	9.6	5.6
+100	17.6	31.6	31.6	32.0	18.4	20.6	32.0	26.2	12.4	27.8	18.2	29.8	35.0	17.2	22.0	16.6
+150	29.8	41.2	40.2	42.4	29.6	33.0	44.0	37.4	22.0	38.0	30.0	41.0	44.4	29.8	33.2	28.6
+200	40.2	49.2	47.6	50.0	39.2	42.8	52.4	46.4	30.4	46.4	40.4	49.8	51.4	41.0	43.2	39.0
−200	59.8	50.8	52.4	50.0	60.8	57.2	47.6	53.6	69.6	53.6	59.6	50.2	48.6	59.0	56.8	61.0
Tons per day (dry)	46.6	129.9	130.9	60.7	49.8	67.3	92.8	80.8	56.1	78.2	46.5	34.5	52.5	37.9	65.8	42.0
Pulp, gal per min	45.0	82.9	85.0	39.5	55.5	59.7	62.5	63.0	58.9	58.7	45.6	25.5	34.3	40.0	43.4	48.1
Overflow																
Solids, pct	7.54	7.6	7.4	11.7	5.4	4.84	6.3	6.4	3.63	4.62	5.1	6.7	10.0	6.0	11.5	4.7
Mesh, pct																
+48	0.0			0.02	0.05	0.0					1.25	0.04	0.02	0.0	0.0	0.02
+65	0.1			0.08	0.35	0.03					1.60	0.08	0.06	0.03	0.03	0.04
+100	0.2			0.28	0.55	1.13					1.90	0.2	0.22	0.06	0.11	0.07
+150	0.4	2.5	2.0	1.28	0.85	1.38	0.4	1.0	1.0	1.0	2.15	0.5	0.42	0.14	0.35	0.37
+200	1.0			4.68	1.20	1.72					2.40	0.9	1.02	0.29	0.73	0.62
+300	3.6			13.48	2.00	2.33	1.2				2.80	1.3	6.42	0.64	1.74	1.37
−300	96.4	97.5	98.0	86.5	98.0	96.67	98.4	99.0	99.0	99.0	97.20	98.7	93.58	99.36	98.26	98.63
Tons per day (dry)	18.8	29.8	24.8	25.9	13.4	11.4	39.4	15.6	10.7	13.9	9.7	9.2	18.4	15.2	31.0	9.9
Gal per min	41.2	62.2	53.0	35.0	47.3	40.65	15.5	39.2	47.7	48.8	32.8	22.1	29.85	36.5	33.3	40.3
Underflow																
Solids, pct	68.3	50.5	38.8	69.7	50.2	37.2	44.3	38.1	40.8	54.6	36.6	69.6	69.6	65.7	41.9	47.3
Mesh, pct																
+48	3.2	10.2	6.0	11.4	1.2	2.4	6.4	4.4	5.4	6.4	1.4	4.4	13.8	1.2	3.0	1.2
+65	10.4	24.0	15.2	34.4	6.6	8.2	19.6	14.8	12.4	18.0	7.2	16.6	34.6	7.2	11.0	7.4
+100	28.0	38.0	27.0	58.0	20.6	26.6	36.8	31.8	25.8	36.4	23.8	36.6	56.2	23.4	26.4	24.2
+150	47.6	51.6	39.2	73.4	37.2	43.0	50.0	45.0	39.4	50.6	38.0	51.6	71.0	42.0	41.2	40.8
+200	63.8	61.4	50.0	83.8	52.2	56.0	59.8	56.2	51.4	61.8	50.6	63.6	81.8	58.6	52.6	53.2
−200	36.2	38.6	50.0	16.2	47.8	44.0	40.2	43.8	48.6	38.2	49.4	36.4	18.2	41.4	47.4	46.8
Tons per day (dry)	27.9	99.1	106	34.8	36.4	55.9	77.2	65.2	45.5	64.2	36.9	25.3	34.1	22.7	34.8	32.1
Gal per min	3.78	20.7	32.1	4.6	8.2	19.1	23.1	23.8	11.2	9.9	12.8	3.32	4.5	3.52	10.1	7.87
Weight recovery, pct	59.8	76.9	81.1	57.3	73.2	83.1	83.3	80.7	81.0	82.2	79.2	73.3	65.0	59.8	52.9	76.5

Table X. Fine Classification of Sand in the DorrClone

Material	Sand			Mill Tailings		
Test	1	2	3	4	5	6
Cyclone, in. diam	6	6	6	3	3	3
Feed nozzle, sq in.	0.75	0.75	0.75	0.19	0.19	0.75
Vortex finder, in. diam	1	1⅜	1⅜	0.49	0.49	1.38
Apex, in. diam	< ½	< ½	< ½	7/16	7/16	¾
Pressure, psi	35	35	5	40	40	30
Feed, pct solids	2.6	2.16	4.42	32.6	23.9	25.4
Overflow, pct solids	1.6	1.6	4.0	16.3	9.21	13.2
Underflow, pct solids	71.2	55.0	49.4	70.3	69.0	71.6
Weight underflow: weight feed	0.301	0.271	0.103	0.65	0.71	0.501
Feed, gal per min	36.3	54.1	23.4	19.6	15.7	62.4
Overflow, gal per min	36.0	53.7	23.2	15.5	13.1	53.8
Underflow, gal per min	0.3	0.4	0.2	4.1	2.6	8.6
Separation, microns	25	32	42	35	27	74
Solids, sp gr	2.65	2.65	2.65	2.65	2.65	2.65

average of 51.8 gpm of 23.5 pct solids pulp, producing 41.5 gpm of reject slimes at 1.92 pct solids and 10.3 gpm of conditioner feed containing 94.1 pct of the feed solids at 68.2 pct solids.

Magnesite Ore

Laboratory tests were made for desliming magnesite ore using a 3-in. DorrClone. Seven tests from this study are reported in Table VI. The per cent solids in the feed and the nature of the feed are essentially the same in all tests. Table VI shows that for a given set of cyclone dimensions the throughput, the recovery, and the underflow density are functions of the feed pressure.

This application of the DorrClone removed all the objectionable fine slime with a perfect recovery of useful product of high density, 71 to 79 pct solids.

Dewatering

The DorrClone is convenient for dewatering or densifying where loss of the fines that will necessarily be contained in the overflow is permissible. A fluid pulp may be pumped to the site where the cyclone will extract the solids from the pulp and discharge them at a high, controlled density. The cyclone, which requires little more room or supporting structure than the pipe line itself, can be placed above conditioners, underground, or in small, inaccessible places where placement of conventional equipment would be impossible.

Mine Fill

At a Howe Sound property, test work is in progress to use the cyclone in dewatering a mine fill produced from a deslimed mill tails. Some results from a series of tests conducted by V. A. Zandon of Howe Sound are reported in Table VII.

A sand having good drainage properties has been produced by desliming the mill tails with a cyclone. This desliming would proceed on a 24-hr basis above ground where the sand would be stored. For 8 hr each day this sand would be washed at 45 to 50 pct solids into a sump, from which it would be pumped below ground. There, a cyclone located at the exact point where fill was to be placed would remove the solids from the pulp. The water containing some slimes could then be pumped away.

The tests reported in Table VII are concerned with the second or underground phase of this work. With a 24-in. DorrClone using 27 to 40 psi feed pressure and 42 to 48 pct solids in the feed pulp, Mr. Zandon has been able to discharge 33 to 53 tons per hr of coarse solids at 66 to 69 pct solids. As much as 92 pct of the solids pumped below ground were removed by the cyclone.

Pyrite Concentrate

A DorrClone has been installed as a test unit in Plant X to deslime and dewater a pyrite concentrate in preparation for further treatment. Results are given in Table VIII.

With a feed of 14.5 to 24 pct solids, 39 to 70 pct —200 mesh, a 3-in. cyclone operating at 11 to 19 psi will process 25 to 40 gpm of pulp. The underflow was

67 to 75 pct solids and 30 to 55 pct —200 mesh; and the overflow 28 to 5 pct solids, 92 to 97 pct —200 mesh. Under these conditions 61.2 to 89.4 pct of the feed reported to the underflow.

Zinc Tailing

The tails from a zinc flotation circuit are deslimed and dewatered in preparation for further treatment. Table IX contains results obtained from a 3-in. cyclone operated as a test unit in this plant. Pulp was processed at a rate of 50 to 130 tons per hr at 13 to 22 pct solids, 19 to 50 psi; 98 pct of the +200 mesh feed was recovered, and 50 pct of the slimes removed. An underflow of 68 to 70 pct solids was produced.

Fine Size Classification

The DorrClone is capable of producing separation in which the top size in the overflow is as fine as 10 microns. The top size in any specific instance is determined by the cyclone proportions and pulp densities but is easily varied and controlled. It can be used in almost any hydroseparation with the advantage that it produces cleaner and denser underflows than a hydroseparator and requires no chemical dispersing agent.

Sand

Tailor-made sands were produced by making fine size classifications on products from 1—a silica deposit and 2—a mill tailing of high grade quartz.

The data of Table X are presented as examples of the flexibility of the DorrClone resulting from changes in vortex finder, feed nozzle, pressure, and densities. Through adjustment of these factors a wide range of products and product qualities is possible.

The complexity of the relationship of the extremely large number of variables results in an apparent inconsistency from test to test with reference to capacity and separation. A complete understanding of this situation results only from an exhaustive study of each variable. Failure to do this has resulted in inexperienced investigators abandoning the cyclone in instances where it was later found to have great possibilities.

Silver Tailings

In an old silver tailings dump it was found that the coarse particles contained a core of high grade ore, but the fine particles had been completely depleted by the original leach and were worthless. It therefore was desirable to rework only the coarse particles. The DorrClone produced a fine size classification rejecting the fines. The recovery of the total silver varied inversely as the grade of the coarse product, of course, but was always considerably higher than the total weight recovery. These results are shown in Table XI.

Table XI. Fine Size Classification on Silver Tailings with the DorrClone

Test No.	1	2	3	4	5
Cyclone, in. diam	3	3	3	3	3
Feed nozzle, sq in.	0.30	0.30	0.30	0.75	0.75
Vortex finder, in. diam	0.62	0.62	0.62	1.38	1.38
Apex, in. diam	⅛	½	½	⅛	⅛
Pressure, psi	40	15	15	5	15
Solids, pct					
Feed solids, pct	19.7	19.3	18.2	29.6	30.3
Overflow solids, pct	7.0	7.0	8.6	23.3	25.4
Underflow solids pct	72.3	66.1	70.1	70.8	70.9
Weight underflow per weight feed	0.714	0.712	0.60	0.315	0.252
Feed, gal per min	21.3	11.3	14.2	25.9	46.3
Overflow, gal per min	18.6	9.8	12.8	23.5	42.9
Underflow, gal per min	2.7	1.5	1.4	2.4	3.4
Silver recovery, pct	78.0	76.8	68.4	46.4	40.3
Silver recovery: weight recovery	1.09	1.08	1.14	1.47	1.60
Silver per ton, oz.					
Heads	1.25	1.25	1.25	1.25	1.25
Overflow	0.83	1.01	0.80	0.92	0.80
Underflow	1.32	1.31	1.30	1.73	1.80
Solids, sp gr	2.65	2.65	2.65	2.65	2.65

Table XII. Fine Classification of Phosphate Rock with the DorrClone

Test	1	2	3	4
Cyclone, in. diam	3	3	3	3
Feed nozzle, sq in.	0.75	0.75	0.75	0.75
Vortex finder, in.	1.38	1.38	1.38	1.38
Apex, in. diam	⅜	⅜	⅜	⅜
Pressure, psi	5	10	20	40
Solids, pct				
Feed	7.10	7.22	7.00	7.43
Overflow	6.27	6.47	6.31	6.83
Underflow	46.9	48.7	49.7	50.4
Weight underflow: weight feed	0.135	0.121	0.114	0.085
Feed, gal per min	23.3	38.4	49.2	65.5
Overflow, gal per min	22.9	37.9	48.6	64.8
Underflow, gal per min	0.35	0.50	0.57	0.66
Phosphate recovery, pct	30.5	29.0	27.0	23.5
Phosphate recovery: weight recovery	2.26	2.40	2.37	2.37
Bone phosphate lime, pct				
Heads	27.2	26.2	25.8	24.8
Overflow	21.9	21.2	21.2	20.2
Underflow	61.5	62.8	61.2	58.6
Solids, sp gr	2.65	2.65	2.65	2.65

Phosphate Rock

The DorrClone was used to produce a fairly good grade of brown phosphate rock from an old deposit left from an impounded debris. The particles within a marketable size range were of high bpl (bone phosphate of lime). Therefore, the cyclone was used to eliminate the finer sizes and recover the coarser sizes of particles. Approximately 90 pct of the solids were rejected, but about 25 pct of the phosphate was retained at a grade of about 60 bpl. The results are reported in Table XII.

Degritting

Grits and cores may be removed effectively from a slurry or slip by the DorrClone. The increased acceleration resulting from centrifugal forces acting on the grits give them enough force to overcome the yield strength of the pulp. Grit removals of 90 pct or more of that entering with feed are common without excessive dilution of the pulp. Table XIII contains data collected from laboratory tests on this application.

Summary

With a DorrClone, flexibility of both mesh of separation, and volumetric capacity are possible while maintaining constant underflow density. This is possible through the use of an adjustable feed nozzle, interchangeable vortex finders, and a positive-acting automatic control of the apex aperture. This automatic control system uses as its intelligence a vacuum that exists as an inherent characteristic of the air core of an operating DorrClone and that can be correlated with underflow density This control has been used with the tire type of adjustable aperture to hold the per cent solids of the underflow to within ±3 pct of its mean value when the feed per cent solids was fluctuating over a range of ±75 pct of its mean value.

Through automatic adjustments to yield maximum underflow density, the DorrClone squeezes out a maximum amount of the water present in the voids of its underflow and thereby eliminates a maximum amount of slimes from the underflow. This feature enables the DorrClone to eliminate in one stage as

Table XIII. Laboratory Degritting with the DorrClone

Material	Slaked Lime										Clay		
Cyclone, in. diam	6	6	6	6	6	6	6	6	6	6	3	3	3
Feed entrance, sq in.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.375	0.375	0.375
Vortex finder, in. diam	1.38	1.38	1.38	1.38	1	1	1⅜	1⅜	1¼	1¼	0.5	0.5	0.5
Apex, in. diam	1	1	1	¼	⅞	13/16	1	1 1/16	1	1	0.25	0.25	0.25
Pressure, psi	60	30	30	35	35	20	20	10	25	15	35	75	75
Solids, pct													
Feed	12.6	14.9	14.6	8.03	37	38.2	34.0	34.7	34.4	33.2	29	29	30.0
Overflow	11.6	14.4	14.0	7.94	34.2	33.6	30.8	31.6	31.7	31.5	26.9	26.5	28.6
Underflow	23.1	19.5	16.9	51.74	63.2	61.1	64.1	58.3	65.7	86.6	38.2	40.8	41.4
Weight underflow: weight feed	0.154	0.115	0.232	0.014	0.165	0.267	0.179	0.195	0.152	0.115	0.248	0.252	0.155
Feed, gal per min.	71.2	47.3	37.6	64.2	40.6	34.7	43.4	28.7	40.4	34.3	8.86	13.9	13.5
Overflow, gal per min	65.6	43.3	30.3	64.1	37.1	31.7	40.0	26.4	37.4	31.6	7.31	11.5	12.1
Underflow, gal per min	5.6	4.0	7.3	0.1	3.5	3.0	3.4	2.3	3.0	2.7	1.55	2.4	1.4
Removal of refuse, pct													
+200-mesh					80.9	80.2	82.1	83.7	80.9	80.4	96.5	99.5	98.3
+325-mesh	96.9	95.2	92.3	85.6									
Size analysis													
Feed +200-mesh					0.81	1.90	1.90	1.50	1.91	2.04			
+325-mesh	4.78	3.06	2.79	0.26							3.01	2.95	2.32
Overflow +325-mesh	0.178	0.106	0.28	0.04							0.054	0.032	0.051
Underflow +325-mesh	30.7	25.3	11.14	15.9							11.94	11.72	14.7
Solids, sp gr	2.2	2.2	2.2		2.2	2.2	2.2	2.2	2.2	2.2	2.52	2.52	2.52

high as 90 pct of the slimes present in the feed pulp.

The mechanical dispersion and high centrifugal forces present in the DorrClone make it especially suitable for treating pulps that are naturally flocculent. This enables classifications as fine as 10 microns and degritting of plastic pulps with dilution at which the critical sizes in the feed would not settle in conventional equipment. Thus, without penalizing the effectiveness of the separation both overflow and underflow from the DorrClone can be of higher density than the products of a hydroseparator in the corresponding operation.

Acknowledgments

The author would like to express his thanks to the Dorr Co. for permission to present this paper and to many friends for their kind contributions. Among these are: J. L. Weaver and O. H. Wright of American Cyanamid; E. B. Brower, C. C. Chapman, and J. C. Long of Virginia-Carolina Chemical Co.; V. A. Zandon and H. A. Pearse of Howe Sound; E. W. Greene of Minerals Separation, North American Corp., and colleagues and coworkers in the Dorr Co.

But above all the author thanks E. J. Roberts whose understanding of the fundamentals of the cyclone formed the basis of this work and whose patience in consultation led to this writing.

References

[1] H. E. Criner: The Vortex Thickener. Presented before International Conference on Coal Preparation, Paris, France, June 1950.

[2] D. A. Dahlstrom: Cyclone Operating Factors and Capacities on Coal and Refuse Slurries. *Trans.* AIME (1949) **184**, p. 331-334; Mining Engineering (September 1949) TP 2633P.

[3] M. G. Driessen: Theory of Flow in a Cyclone. Presented before International Conference on Coal Preparation, Paris, France, June 1950.

[4] M. G. Driessen: The Use of Hydraulic Cyclones in Thickeners and Washers in Modern Coal Preparation. *Trans.* AIME (1948) **177**, p. 240; *Coal Technology* (August 1947) TP 2135.

[5] M. G. Driessen: The Use of Centrifugal Force for Cleaning Fine Coal in Heavy Liquids and Suspensions. Institute of Fuel *Journal* (1945) **19**, p. 33-45.

[6] H. F. Yancey and M. R. Geer: The Cyclone as a Thickener of Coal Slurry. *Trans.* AIME (1948) **177**, p. 262; *Coal Technology* (February 1948) TP 2351.

[7] Wm. B. Stephenson: Automatic Controls on Sand Pumps. *Trans.* AIME **187**, p. 801; Mining Engineering (July 1949) TP 2871B.

[8] M. G. Driessen and H. E. Criner: Cyclone Thickener Applications in Coal Industry. *Trans.* AIME (1950) **187**, p. 102-108; Mining Engineering (January 1950) TP 2735F.

[9] O. H. Wright: Cyclones for Desliming and Dewatering in the Land Pebble Phosphate Field. Presented before Florida Section, AIME Tampa Meeting (November 1949).

[10] Arthur Crago: Three New Steps in Treating Florida Phosphate Rock. *Engineering & Mining Journal* (November 1950) **151**, p. 78-83.

[11] D. A. Dahlstrom and R. W. Maeser: Cyclone Elimination of Contaminating Solids from Process Water. *Trans.* AIME (1948) **177**, p. 277; *Coal Technology* (November 1948) TP 2471.

[12] J. W. Hyer: Heavy-density Separation—A Review of Its Literature. *Quarterly*, Colorado School of Mines, **43**, p. 36-42.

[13] R. I. Kingman: Cyclones Prove Satisfactory for Thickening, Desliming Flotation Feed. Mining Engineering **187**, p. 867-870 (August 1950).

Correction

In the June 1951 issue: *Economic Aspects of Ground Water in Florida* by V. T. Stringfield and H. H. Cooper, Jr. P. 527, in the caption for Figure 1 credit should be given to David B. Ericson and the Florida Geological Survey for the preparation of the original map on which the figure is based.

Comparative Results With Galena and Ferrosilicon at Mascot

by D. B. Grove, R. B. Brackin and J. H. Polhemus

THE heavy media separation process plays an outstanding role in the concentration of 4000 tons of zinc ore per day at the Mascot mill of the American Zinc Co. of Tennessee. Of the total tonnage, 72 pct is treated in the heavy media separation plant to reject 56 pct of the ore as a coarse tailing, which has a ready market. Concentrates from this separation are beneficiated further by jigging and flotation. Approximately 25 pct of the total zinc concentrate production is made in the jig mill. Jig tailings are ground and pumped to the flotation circuit where the balance of the production is made. Fig. 1 shows a generalized flowsheet of the mill.

The Mascot ore is a lead-free, honey-colored sphalerite in dolomitic limestone, with lesser amounts of chert and some pyrite. A mineralogical analysis is given in Table I.

After 10 years of successful operation with galena medium and treatment of nearly 10,000,000 tons of ore, a decision to convert to ferrosilicon was made early in 1948 because of the increasing price of galena and consequent high operating costs. The conversion was made on Nov. 6, 1948, and the results obtained since that time have shown remarkable improvement over those made with galena. The comparisons given in this report cover the first 6 months of 1950 as representing the ferrosilicon operation, and the year 1947 as representing the galena operation. This was the last full year in which galena was used exclusively and is representative of the best work done during the 10 years of operation with this medium. After only 2 years' operating experience with ferrosilicon and treatment of 1,807,585 tons many advantages have been revealed and are summarized in Table II.

Table I. Mineralogical Analysis of Mill Feed, Pct

Calcium carbonate	49.5
Magnesium carbonate	35.2
Iron oxide and aluminum oxide	1.5
Zinc sulphide	4.5
Insoluble	9.3
	100.0

Table II. Comparative Data, Galena and Ferrosilicon

	Galena[a]	Ferrosilicon[b]	Difference
Operating costs per ton milled, ct.	21.21	9.12	12.09
Medium consumption per ton milled, lb	0.20[c]	0.15	0.05
Reagent consumption per ton milled, lb	0.45	0.02	0.43
Tailing assay, pct Zn	0.310	0.297	0.013
Concentrate, pct Zn	12.08	10.33	1.75
Heavy media separation recovery, pct	89.38	90.22	0.84
Mill feed rate, tons per hr	153	166	13
Heavy media separation feed rate, tons per hr	100	120	20
Tons milled per heavy media separation man shift	350	620	270
Mill feed to coarse tailings, pct	51.0	56.7	5.7
Lost mill time, pct	5.6	5.0	0.6
Power consumption, kw-hr per ton	2.06	1.92	0.14

[a] 1947.

[b] First 6 months of 1950.

[c] Net consumption after deducting credit for reclaimed waste galena. Consumption of new galena was 1.320 lb per ton milled. For entire life of galena operation, a credit of 40 pct of the value of the new galena added was realized from the sale of waste galena.

Development

Prior to the introduction of the heavy media process, all the mill feed was crushed through 5/8 in. and treated by jigging. A finished tailing assaying 0.66 pct Zn was made on rougher bull jigs, and cleaner jig tailings were ground for treatment by flotation.

The first test work on the sink-and-float method of mineral beneficiation was carried out at Mascot in 1935, using a 3-ft cone and galena medium for batch tests. The following year a 6-ft cone was installed for pilot-plant work. This unit became a part of the mill circuit on March 1, 1936, and handled a gradually increasing tonnage in the next 2 years as the process developed to the point where it could treat all the + ⅜-in. material in the mill feed. Coarse jigging was then discontinued on March 1, 1939, and all coarse tailings have been made by the heavy media separation plant since that time.

Feed Preparation: The original feed preparation plant consisted of a drag washer followed by two 4x10-ft Allis-Chalmers washing screens. A surge bin and two additional 5x12-ft AC washing screens were added in 1943. Use of primary and secondary washing screens was found essential to provide the cleanest possible feed for the cone and thereby avoid excessive contamination of the galena medium. Improved washing was obtained by replacing the drag washer with a 7x20-ft Allis-Chalmers scrubber, shown in Fig. 2, which has been in service since May 1944. Throughout the life of the galena operation, delivery of extremely muddy ore to the mill overloaded the medium cleaning system, and it frequently was necessary to cut off the feed and clean the medium for several hours until its normal viscosity had been re-established. The cleaning circuit

D. B. GROVE, Mill Superintendent, R. B. BRACKIN, Member AIME, Assistant Mill Superintendent, and J. H. POLHEMUS, Member AIME, Metallurgist, are with the American Zinc Co., Mascot, Tenn.

Discussion on this paper, TP 3112B, may be sent to AIME before Sept. 28, 1951. Manuscript Dec. 13, 1950. St. Louis Meeting, February 1951.

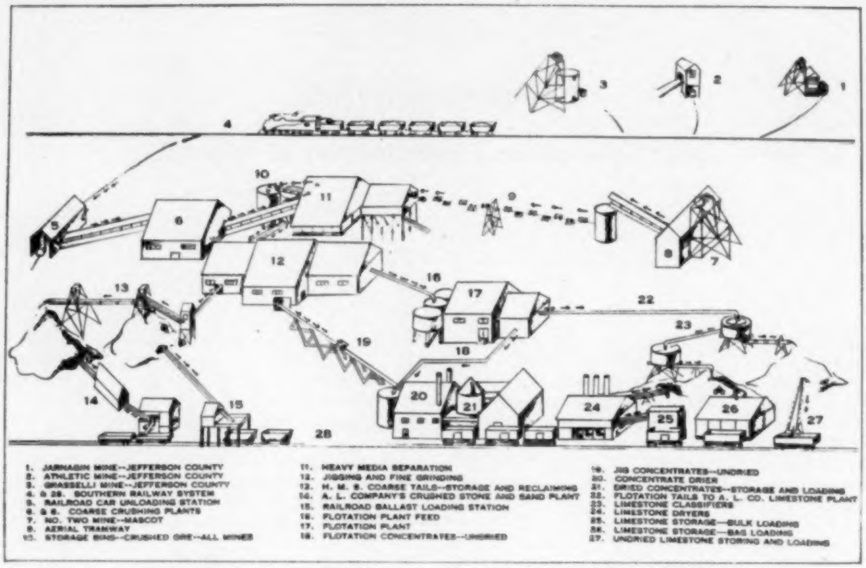


Fig. 1—Generalized flowsheet of American Zinc Co. and American Limestone Co. operations.

was operated each weekend to remove the contaminants that had built up in the medium during the week.

Medium Cleaning: The galena was cleaned originally by flotation, but this method was abandoned late in 1936 because it failed to reject enough of the contaminants and also because the reagents used to float the galena created froth and an unstable medium in the separatory cone. Various combinations of screens, settling tanks and sand and slime tables were tried in the next 2 years, and eventually a satisfactory cleaning circuit was developed. Trisodium phosphate was used as a dispersant for slimes and proved invaluable in maintaining the fluidity of the medium. Clean galena from the tables was returned to a storage tank ahead of the cone, and the table tailings were pumped to a storage pond. Periodic cleanups of these sands were made for recovery of their lead and zinc values. Extremely fine galena from the final settling tank was also pumped to a pond and reclaimed yearly for shipment to a lead smelter. Throughout the life of the galena operation, the returns from this reclaimed material amounted to 40 pct of the cost of the new galena used.

Conversion to Magnetic Medium

Following the decision to convert from galena to ferrosilicon, plans for the new circuit were prepared under the direction of Robert Ammon, the company's Chief Metallurgist, and R. H. Lowe of the American Cyanamid Co., who followed all details of the changeover and to whom much credit is due for the success of the new circuit. A 10½-ft cone was installed in July 1948 to replace the old 9-ft cone, see Fig. 3. All necessary equipment for the new medium cleaning circuit then was installed adjacent to the cone without any interruption of normal operations. The conversion to ferrosilicon took place on Nov. 6, 1948 over a regular weekend shutdown. The galena was pumped out of the circuit to storage ponds, and a thorough cleanup was made. This work was completed in three shifts. The circuit was filled with 60 tons of 100 mesh ferrosilicon on the following day, and a few necessary adjustments to the new equipment were made. The feed was put on at 2:30 pm on Nov. 8 and was not taken off again that day. The cone was handling its full tonnage rate within an hour after starting and no operating difficulties were encountered. The circuit as originally constituted has remained unchanged, except for the addition of a second magnetic separator. This machine was put in on a trial basis for the Stearns Magnetic Mfg. Co. Its performance compared favorably with that of the Dings machine, which was part of the original installation, and it has been kept in service as insurance against a breakdown on either of the separators. In addition, use of primary and secondary separators has been beneficial in keeping medium consumption at a very low level.

Ferrosilicon Circuit

The flowsheet of the circuit is extremely simple, see Fig. 4. The −2-in. ore from the mill bins is conveyed to a 7x20-ft Allis-Chalmers rotary scrubber, where it is subjected to intensive washing to liberate the fines from the coarser pieces of rock. The scrubber discharges onto two 5x12-ft Allis-Chalmers low-head washing screens equipped with 5/16-in. sq hole woven wire cloths. Oversize from these screens is conveyed to the cone. The tonnage rate as determined by a Merrick Weightometer is recorded on a Rateograph at the cone operating floor. The −5/16-in. material from the wash screens is dewatered by a 30 in. x 75-ft belt drag. The sands are delivered to the jig mill feed bin, and the −65 mesh drag overflow material is thickened and pumped directly to flotation.

The −2 +5/16-in. feed is treated in a 10½-ft separatory cone equipped with an 8-in. internal air

lift for removal of concentrates. Details of the cone and air jet are shown in Figs. 5 and 6. Rakes rotating at 5 rpm are mounted on the air lift, which serves as the drive shaft. An air consumption of 90 cfm is required to elevate the concentrates to the top of the air lift. The air is supplied at 100 psi pressure by a 568-cfm Ingersoll Rand compressor driven by a 105-hp motor. This compressor was used for the galena operation, which required much higher air consumption. Although too large for the present operation, it has been kept in service rather than purchase a smaller unit. An adjustable air jet permits the operator to control the exact point at which air enters the air lift. This feature is valuable in controlling the gravity of the bottom medium, and thus the differential in the cone. At present the tip of the jet is ½ in. above the bottom of the 8-in. air lift, and excellent control is obtained at this point. The jet is made of 1½-in. stainless steel shafting with a ⅜-in. diam hole in the center to carry the air. The outer surface of the jet is threaded so it can be raised or lowered through a packing gland by turning a handwheel. Plows are mounted on the bottom of the rakes to prevent build-up of medium and tramp steel on the bottom plate. These plows are cut out of discarded ball mill liners and bolted to the bottom of the rakes. They normally last from 1 to 2 years.

The concentrate airlift discharges onto a 3x6-ft drainage screen, and the medium drains back onto the surface of the cone through a punch plate with 2-mm round holes. Use of the smallest possible hole at this point has proved advantageous in removing fine zinc from the bottom medium and preventing an accumulation of this material in the cone, with a resultant lowering of the bottom gravity. Washing of the concentrates takes place on a 4x10-ft screen using a ⅛-in. round hole punch plate. Washed concentrates are crushed through ⅜ in. x 3-ft short head Symons cone crusher operating in closed circuit with a 4x10-ft screen. The undersize from this screen joins the dewatered −5/16-in. material from the feed preparation screens and is conveyed to the jig mill.

Tailings overflow the cone through a weir 42 in. wide onto a 4x8-ft drainage screen equipped with a ¼-in. round hole punch plate. The depth of medium and rock in the weir is 4 in. during normal operations. The oversize of the screen passes to a

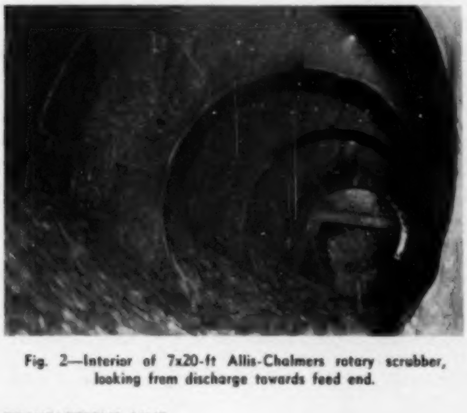


Fig. 2—Interior of 7x20-ft Allis-Chalmers rotary scrubber, looking from discharge towards feed end.

Fig. 3—10½-ft diameter separatory cone. Tailing overflow weir at left center, concentrate drainage screen at right.

5x12-ft washing screen using ¼-in. sq hole cloths. The clean tailings are then conveyed to storage piles for sale as railway ballast and concrete aggregate.

The undersize from the tailings drainage screen enters a pump sump and is returned to the cone by a 6-in. Wilfley pump. A gate under the screen is used to divert a portion of the undersize to the cleaning circuit, and in addition, a continuous light overflow from the pump sump goes to the cleaning circuit. All the undersize from the tailing and concentrate wash screens is handled by a 4-in. Wilfley pump, which delivers this contaminated medium to a 20-ft Dorr thickener. Before entering the tank, the material passes through a permanent Alnico magnet, which causes the ferrosilicon particles to flocculate and settle rapidly. The thickened, dirty medium is pumped by a 2-in. Wilfley pump to the primary magnetic separator, a 24-in. Stearns machine. Its tailing is retreated in a 36-in. Dings Crockett magnetic separator shown in Fig. 7. Clean medium from both machines enters a 48-in. Colorado Iron Works densifier, which thickens it to 3.20 sp gr and delivers it through an ac demagnetizing coil to the medium pump sump for return to the cone. Overflow from the densifier is returned to the 20-ft Dorr thickener. The tailings and overflow from the secondary magnetic separator, which contain excellent values in fine zinc, are dewatered and handled in the jig and flotation circuits. Thickener overflow water is used on the concentrate and tailings wash screens.

Screen analysis and zinc distribution in the heavy media separation plant are given in Table III.

The five pumps in the circuit have the following functions: (1) 6-in. Wilfley, returns cone overflow medium and densifier discharge to cone. (2) 4-in. Wilfley, delivers dirty medium to 20-ft thickener. (3) 2-in. Wilfley, delivers thickened dirty medium to magnetic separators. (4) 2½-in. Fairbanks-Morse, thickener overflow to sprays on wash screens. (5) 1½ RV-5 Cameron motorpump, clean water to sprays on magnetic separators.

A cleanup elevator with an 18 in. x 70-ft belt is used for three purposes: 1—To handle all cleanup material from the basement, 2—To elevate the undersize from the tailings wash screen for delivery to the 4-in. pump, and 3—To add new medium to the circuit. The elevator discharge passes through the concentrate wash screen for removal of all +⅛-

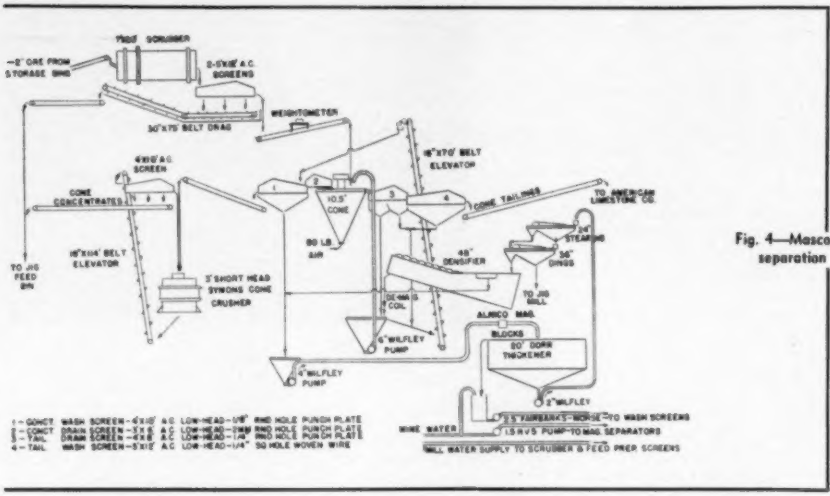


Fig. 4—Mascot heavy media separation flowsheet.

in. material, and is then pumped to the medium cleaning circuit. A second elevator employing a 18 in. x 114-ft belt, raises the crushed cone concentrates to a 4x10-ft screen, which closes the circuit on this product. The housings of both elevators are made of 7 gage tunnel liner plate. This material, which is normally used for culverts, has proved ideal as an elevator enclosure. Each housing has elliptical ends and straight sides, with a major axis of 6 ft (parallel to sides) and a minor axis of 4 ft. The plates are 18 in. in depth and flanged for a bolted connection between rings. The elevator drive is mounted on a frame at the top of the housing.

The original circuit had only one magnetic separator, the 36-in. Dings machine. It gave excellent service and medium recovery of 99.9 pct. The 24-in. Stearns machine was located so it could be used as either a primary or secondary separator. It has proved more convenient to operate it as a primary separator, since no additional pumping is necessary. Its tailing is retreated in the Dings machine, which picks up any losses that may occur because of a temporary overload on the Stearns. Medium is being cleaned at a rate of approximately 9 tons per hr, with a loss of 13.2 lb per hr, or 0.95 g per gal of separator tailings. The exceptionally high recovery made by this circuit justifies the continuous use of two separators, although one is adequate to handle the load under normal circumstances.

The distribution of the total ferrosilicon loss of 0.15 lb per ton milled is shown in Table IV. Slightly more than 50 pct of the loss is in the tailing from the cleaning circuit. Medium adhering to the cone products represents 30.3 pct of the loss, and 16.5 pct is unaccounted for. The greater part of this material is probably lost through oxidation of the ferrosilicon.

All washing is done with Spraco ramp-bottom nonclogging nozzles, shown in Fig. 8, which have proved highly satisfactory in this type of service. No. 9R nozzles, each of which deliver 7.4 gpm at 10-lb pressure, are used on the feed preparation screens with 15 nozzles per screen in three rows of five nozzles per row. This gives a water consumption of 111 gal per screen, or 1.30 gal per ton of ore washed. No. 7R nozzles, each delivering 6.4 gpm at 18-lb pressure, are used on the concentrate and tailing wash screens. The concentrate screen has eight nozzles in two rows of four each, supplying a total of 51.2 gpm or 2.6 gal per ton of concentrates washed. There are 15 nozzles over the tailing wash screen in three rows of five each, delivering 96 gpm or 1.0 gal per ton of tailings washed. The total water consumption for all screen washing is 369.2 gpm. Water used in the scrubber amounts to 520 gpm.

Table III. Screen Analyses and Zinc Distribution, Heavy Media Separation Plant

Screen Size, In.	Wt, Pct	Cum Wt, Pct	Zn, Pct	Cum Zn, Pct	Total Zn, Pct	Total Cum Zn Pct,
CONE FEED						
1½	6.46	6.46	1.16	1.16	4.84	4.84
1	27.75	34.21	2.40	2.28	27.72	32.56
¾	24.12	58.33	2.21	2.23	22.22	54.78
½	21.36	79.69	2.46	2.31	21.93	76.71
⅜	10.32	90.01	2.70	2.35	11.63	88.34
5/16	4.80	94.81	2.52	2.36	5.04	93.38
¼	4.29	99.10	2.91	2.39	5.21	98.59
−¼	0.90	100.00	3.78	2.40	1.41	100.00
TOTAL	100.00		2.40		100.00	
CONE CONCENTRATES						
1½	4.46	4.46	7.98	7.98	3.70	3.70
1	27.01	31.47	9.05	8.90	25.42	29.12
¾	22.79	54.26	10.08	9.40	23.90	53.02
½	20.59	74.85	9.76	9.50	20.90	73.92
⅜	10.67	85.52	10.30	9.60	11.43	85.35
5/16	4.98	90.50	11.02	9.67	5.71	91.06
¼	5.12	95.62	9.80	9.68	5.22	96.28
−¼	4.38	100.00	8.15	9.62	3.72	100.00
TOTAL	100.00		9.62		100.00	
CONE TAILINGS						
1½	4.31	4.31	0.21	0.21	3.08	3.08
1	29.30	33.61	0.29	0.28	28.40	31.48
¾	23.74	57.35	0.25	0.27	20.50	51.98
½	21.05	78.40	0.33	0.28	23.38	75.36
⅜	10.62	89.02	0.35	0.29	12.44	87.80
5/16	4.84	93.86	0.31	0.29	5.12	92.92
¼	5.20	99.06	0.28	0.29	4.98	97.90
−¼	0.94	100.00	0.66	0.29	2.10	100.00
TOTAL	100.00		0.295		100.00	

Heavy Media Separation Circuit

The normal operating week in the heavy media separation plant begins at 3 pm Monday, after all necessary general mill repairs have been carried out on day shift. Operations are continuous until

midnight on Friday or Saturday, depending upon whether the plant is on a 5 or 6-day week. After the feed is cut off, the medium is diluted and the air jet is opened wide to remove all rock from the cone through the air lift. Three extra bags of lime are added to the cone to prevent any possible hydrolysis and setting up of the medium while it is in storage. The medium circulating pump is then stopped, and all medium in the pump sump and cone is drained into the basement. These steps are completed in about 45 min. The medium is drained into the clean-up elevator and returned to the densifier through the regular cleaning circuit until the densifier is full. This procedure requires about 1 hr. The remaining medium, representing perhaps 25 pct of the total circuit load, remains in the basement over the weekend. Two hours are required on Monday to fill the cone from the densifier and wash up the medium in the basement, and the circuit is ready for operation at the end of that time. This method of shutting down the plant has proved very simple and satisfactory. The medium has been stored in this manner for as long as 2 weeks, and no difficulty was experienced in resuming operations. It is essential, however, to add an adequate amount of protective lime if the medium is to be inactive for any appreciable length of time.

Control of the cone operation is simple, and under all normal conditions consists entirely of adjusting the amount of dilution water being added to the surface of the medium in the cone. The densifier spiral is kept at the bottom of the tank, and excess medium is stored in the densifier only when the feed is off the cone and on weekends when the plant is down. The operator checks the gravities every hour, using a 1 liter density bucket and a scale graduated to give a direct specific gravity reading. The cone top gravity is kept at 2.83. A higher reading calls for increased dilution water, and a lower reading for a reduction in the water. Very little

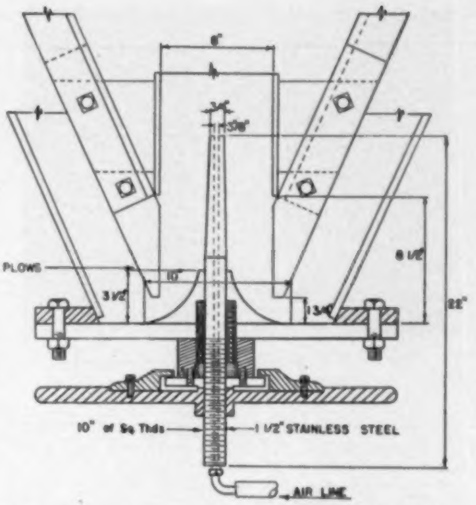


Fig. 6—Cone bottom showing relationship of air jet, air lift, and rakes.

adjustment is necessary as long as a uniform feed to the cone is maintained. Normal practice is to clean about 9 tons of medium per hr, a quantity which is in excess of that actually required to keep the medium clean and maintain the desired viscosity. Thus a margin of safety is provided to take care of any increased fines or moisture in the cone feed. Each day 500 lb of new medium are added to the circuit, and if necessary more is used to maintain the required gravities in the cone. In addition, 50 lb of lime are used daily to prevent hydrolysis of the ferrosilicon. The new ferrosilicon and lime are mixed with water in a small tank equipped with a high-speed agitator. Preparation of the medium in this manner for approximately 1 hr before introducing it into the circuit insures complete wetting and conditioning of the fine ferrosilicon particles and prevents losses as the new medium passes through the cleaning circuit.

When operations began, 60 tons of 100 mesh ferrosilicon were used to load the circuit. During the first few months the differential in the cone was appreciably higher than it is now, because of the newness of the medium and consequently greater average particle size. Approximately 10 tons of magnetite were added in the first 6 months to stabilize the medium and create a differential of about 0.10 between the gravities at the top and bottom of the

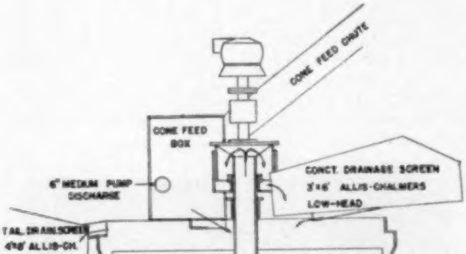


Fig. 5—10½-ft diam separatory cone.

Table IV. Distribution of Ferrosilicon Losses

Product	FeSi, Lb		Total Loss, Pct
	Per Hr	Per Ton Milled	
Magnetic separator tailings	13.2	0.080	53.2
Cone concentrates	2.5	0.015	10.1
Cone tailings	5.0	0.030	20.2
Unaccounted for	4.1	0.025	16.5
TOTAL	24.8	0.150	100.0

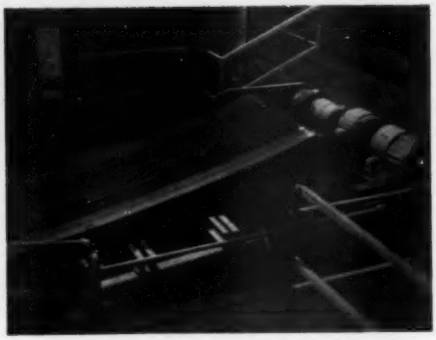


Fig. 7—36-in. Dings Crockett magnetic separator.

cone. After the medium had been in use for several months, its degree of fineness increased to a point where the condition of the early operating months was reversed and the differential began to drop. Changes were made in the circuit to permit cleaning of more medium, and in May 1949, 65 mesh ferrosilicon was substituted for the 100 mesh ferrosilicon formerly used for makeup medium. The coarser grade proved of value in maintaining the desired differential for several months. However, with medium consumption so low it has been difficult to maintain a differential of 0.10 during the past year.

The size of the medium in use in January 1950 is shown in Table V, which gives the results of sedimentation screen analyses run on the medium pump discharge, densifier discharge, and new 65 mesh and 100 mesh ferrosilicon. Pump data are given in Table VI. Only 3.8 pct of the pump discharge was retained on 200 mesh, as compared with 38.3 pct + 200 mesh in the new 65 mesh ferrosilicon. Breaking down of the coarser sizes is caused by attrition in the cone and pumps and usually is compensated for by normal addition of new medium. The rate of addition, which is governed by the medium loss, determines the average particle size in the circuit. At Mascot the medium consumption has been too low to maintain the average particle size that prevailed during the early months of the operation. However, the medium eventually stabilized after a year's operation at a size sufficient to maintain a differential of 0.09 between the top and bottom gravities. Recovery has been excellent and the operation very uniform at this level. A slight increase in differential would be beneficial to the concentrate grade but might have an adverse effect on recovery. This possibility will be investigated during 1951. However, recovery is of prime importance in the plant, and production of a high-grade concentrate is secondary to obtaining the lowest possible tailing assay.

Data on heavy media plant screens are given in Table VII.

The cone overflow rate is 450 gpm of medium at a medium to rock ratio (by weight) of 3.4:1. The 6-in. medium return pump is handling approximately 600 gpm. The difference of 150 gpm between this and the cone overflow rate represents medium that is continuously bypassed back into the pump sump. The overflow rate can be changed if necessary by opening or closing the bypass valve. The concentrate air lift discharges at a rate of 215 gpm with a medium to rock ratio of 7.9:1.

Table V. Sedimentation Screen Analyses of Medium

Screen Size Intervals		New 65 Mesh Ferrosilicon		New 100 Mesh Ferrosilicon		Densifier Discharge		6-In. Medium Pump Discharge	
Microns	Mesh	Wt, Pct	Cum Wt, Pct	Wt, Pct	Cum Wt, Pct	Wt, Pct	Cum Wt, Pct	Wt, Pct	Cum Wt, Pct
200	+65	5.5	5.5	0	0	0.3	0.3	0.9	0.9
147	+100	11.1	16.6	0.6	0.6	0.3	0.6	0.4	1.3
104	+150	11.4	28.0	8.8	9.4	0.6	1.2	0.8	2.1
74	+200	10.3	38.3	21.0	30.4	1.6	2.8	1.7	3.8
44	+325	10.4	48.7	18.0	48.4	4.4	7.2	4.4	8.2
37	+400	26.1	74.8	16.3	64.7	14.2	21.4	20.8	29.0
27.8	+600	12.5	87.3	19.0	83.7	23.7	45.1	29.8	58.8
18.5	+800	8.3	95.6	12.9	96.6	45.8	90.9	36.0	94.8
16.2	+1000	2.0	97.6	2.2	98.8	4.9	95.8	3.4	98.2
8	−1000	2.4	100.0	1.2	100.0	4.2	100.0	1.8	100.0

Table VI. Pump Data

Pump	Connected Hp	Actual Hp	Rpm	Gpm
6-in. Wilfley	40	37	700	600
4-in. Wilfley	15	8.2	770	218
2-in. Wilfley	5	4.4	1160	150
2½-in. Fairbanks-Morse	20	14.7	1250	147
1½-in. RV-5 Cameron motorpump	5	3.7	3450	10

Heavy Liquid Test Work

To determine the sink-float characteristics of the heavy media separation plant feed, a series of heavy liquid tests was carried out at Mascot in November 1949 by R. H. Lowe of the American Cyanamid Co. A composite sample of cone feed, fractionated in heavy liquid (acetylene tetrabromide) at specific gravity increments of 0.025 to 0.05, gave the results shown in Table VIII. Based on a specific gravity of 2.85, which is the true separating gravity for this ore, 84.32 pct of the feed was rejected as a product assaying 0.25 pct Zn. Under actual plant operating conditions, it is assumed that 1 pct near gravity sink material will report in the float. Since this near gravity material (2.85 x 2.90) in the composite assayed 3.50 pct Zn, it is calculated that the lowest average cone tailing that can be expected in the plant will assay 0.28 pct Zn. Under ideal operating conditions, this tailing can be made and has been

Fig. 8—Tailing wash screen showing action of Spraco ramp bottom nozzles.

Table VII. Heavy Media Plant Screens*

	Feed Preparation Screens (Two)	Concentrate Drainage Screen	Concentrate Wash Screen	Tailing Drainage Screen	Tailing Wash Screen
Size, ft	5x12	3x6	4x10	4x8	5x12
Tonnage per screen, tons per hr	83	20	20	100	100
Slope of screen, (up-feed to discharge), deg, min	2 30	4	2	2 30	2
Amplitude, in.	⅜	7/16	3/16	⅜	⅜
Sections per deck	3	1	1	1	3
Life in days					
Feed	26	13	22	16	27
Center	36				28
Discharge	26				29
Mechanism					
Size	3B	2B	2A	2C	3B
Hp	7½	5	5	5	7½
Type of cloth and size of opening	Woven wire, 5/16 in. sq holes, 0.135 in. diam wire	2 mm round hole, punch plate, 16 gage	⅛ in. round hole, punch plate 12 gage with ½ in. sq hole punch plate, 10 gage for protection	⅛ in. round hole, punch plate, 10 gage	Woven wire, ¼ in. sq holes, 0.135 in. diam wire

* All screens Allis-Chalmers low-head, single deck.

Table VIII. Heavy Liquid Fractionation of Cone Feed, November 1949

Product	Wt, Lb	Wt, Pct	Cum Wt, Pct Sink	Cum Wt, Pct Float	Assay Zinc, Pct	Cum Zinc, Pct Sink	Cum Zinc, Pct Float	Zn Recovered in Sink, Pct Product	Zn Recovered in Sink, Pct Cum
Sink 2.964	24.25	6.31	6.31		23.80	23.80		67.60	67.60
2.964x2.90	14.75	3.84	10.15	93.69	8.20	17.90	0.76	14.18	81.78
2.90x2.85	21.25	5.53	15.68	89.85	3.50	12.83	0.45	8.73	90.51
2.85x2.825	131.75	34.25	49.93	84.32	0.30	4.23	0.25	4.63	95.14
2.825x2.80	132.00	34.33	84.26	50.07	0.20	2.59	0.22	3.10	98.24
2.80x2.75	35.50	9.23	93.49	15.74	0.23	2.36	0.25	0.95	99.19
2.75x2.70	16.75	4.36	97.85	6.51	0.33	2.27	0.28	0.63	99.82
Float 2.70	8.25	2.15		2.15	0.18		0.18	0.18	0.18
TOTAL	384.50	100.00			2.22			100.00	

equalled or bettered in 3 months of the plant's 2-year life. The average tailing during this period has been 0.307 pct Zn.

The results of the above test have been plotted in Fig. 9, which gives the weight distribution and zinc recovery plotted against specific gravity. The curve on weight distribution shows that a drop in gravity from 2.85 to 2.84 can be tolerated, but below this point the weight of sink increases rapidly, and at 2.825 a fifty-fifty split by weight would result. This illustrates the necessity for extremely close gravity control in the cone.

A second series of heavy liquid tests was run in October 1950 for comparison with Mr. Lowe's original work. A composite sample of the cone feed was prepared, representing a week's operation in the plant. This sample was fractionated in acetylene tetrabromide at 2.85 sp gr. The sink-and-float portions then were screened and the sizes assayed. The results of this work are tabulated in Table IX.

The results on the cone feed sample check very closely with those obtained in the work done late in 1949, as shown in Table X.

Plant results in October 1950 show that the heavy media separation unit was actually making a tailing of 0.295 pct Zn and a concentrate of 9.62 pct Zn. Using the heavy liquid test on the cone feed as a basis, the highest theoretical recovery possible in the cone is 91.15 pct. Actual zinc recovery made in the plant was 90.49 pct or 99.28 pct of the theoretically recoverable zinc.

Table IX. Heavy Liquid Fractionation of Cone Feed, October 1950

Size	Wt, Pct Of Size	Wt, Pct Of Total	Assay Zn, Pct	Zn Distribution, Pct Of Size	Zn Distribution, Pct Of Total
2x1 in. sink	18.62	6.37	11.14	90.78	29.58
2x1 in. float	81.38	27.84	0.26	9.22	3.01
Total	100.00	34.21	2.29	100.00	32.59
1x½ in. sink	15.01	6.83	14.06	90.63	39.99
1x½ in. float	84.99	38.65	0.26	9.37	4.13
Total	100.00	45.48	2.33	100.00	44.12
½x5/16 in. sink	13.05	1.97	18.83	92.79	15.49
½x5/16 in. float	86.95	13.14	0.22	7.21	1.20
Total	100.00	15.11	2.65	100.00	16.69
−5/16 in. sink	12.66	0.66	22.18	93.07	6.09
−5/16 in. float	87.34	4.54	0.27	6.93	0.51
Total	100.00	5.20	3.04	100.00	6.60
Total sink	15.83	15.83	13.81	91.15	91.15
Total float	84.17	84.17	0.25	8.85	8.85
Total	100.00	100.00	2.40	100.00	100.00

Advantage of Ferrosilicon Circuit

One of the chief advantages of the ferrosilicon circuit lies in its simplicity. When the conversion took place a major reduction in the number of pieces of equipment in service was made. Seven Allis-Chalmers low-head screens, two elevators, two surge bins, and a set of 54x20-in. Garfield rolls were removed from service permanently. The four

Table X. Heavy Liquid Fractionation of Cone Feed at 2.85

	Wt, Pct Nov. 1949	Wt, Pct Oct. 1950	Zn, Pct Nov. 1949	Zn, Pct Oct. 1950	Zn Distribution, Pct Nov. 1949	Zn Distribution, Pct Oct. 1950
Sink	15.68	15.83	12.83	13.81	90.51	91.15
Float	84.32	84.17	0.25	0.25	9.49	8.85

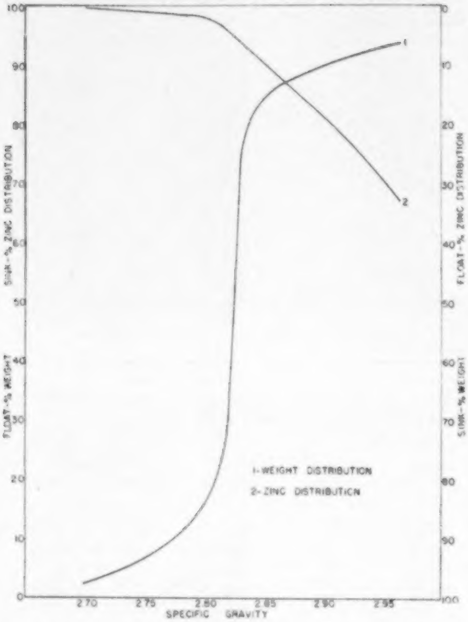


Fig. 9—Results of heavy liquid test on heavy media separation plant feed.

Wilfley tables and six decantation tanks in the old cleaning circuit were replaced with the densifier and two magnetic separators. The total number of pumps in use was reduced from 11 to 5, and the length of the conveying system in the heavy media separation plant and following it was reduced from 760 ft to 513 ft. A 200-ton steel surge bin in the jig mill with one Syntron feeder took the place of a 1000-ton wooden fine ore bin with 14 reciprocating tray feeders.

The efficiency of the magnetic separators used to clean the ferrosilicon permits the handling of extremely wet, muddy ore with little difficulty. Some of the ore received during the rainy seasons in the last 2 years would have taxed the galena cleaning system far beyond its capacity and shut the circuit down. This condition has never developed with ferrosilicon, and the plant has handled normal tonnage and made good results during the periods when the ore was at its worst. At present the mill is treating ores from four of the company's own mines in the area and is also handling two ores on a custom basis.

Table XI. Comparative Heavy Media Separation Costs Per Ton Milled, ¢

Operating	Galena	Ferrosilicon
Medium[a]	9.04	0.90
Reagents[a]	2.25	0.13
Labor	3.53	2.94
Power	1.29	1.30
Sundry	0.20	0.06
Maintenance and Repairs		
Screens and screen cloths	1.70	0.80
All other	3.20	2.09
TOTAL	21.21	9.12

[a] Costs for medium and reagents calculated on basis of prices prevailing at Mascot on Nov. 10, 1950, which were as follows, in cents per lb.

Galena	—	11.30
Trisodium Phosphate	—	5.00
Ferrosilicon	—	6.00
Lime	—	0.65

Another important benefit derived from the adoption of ferrosilicon has been the elimination of the possibility of contaminating the zinc concentrates with lead. Throughout the life of the galena operation there were periodic upsets in the plant which permitted galena to get into the jig and flotation circuits. The resultant high-lead assays on the zinc concentrates caused trouble at the smelter where lead-free zinc oxide is produced from Mascot concentrates. Every effort was made to prevent any leakage of medium into the main mill circuit, and all tailings from the cleaning circuit and fine galena from the final decantation tanks were pumped continuously to settling ponds some distance from the mill. Using ferrosilicon, the magnetic separator tailings are laundered directly to the jig mill circuit for recovery of their zinc content. Periodic reclaiming of this material from a pond has thus been eliminated and over 90 pct of its zinc content is now recovered. This compares with a recovery of about 70 pct made when the sands from the galena cleaning circuit were reclaimed and treated by flotation to obtain a bulk lead-zinc concentrate.

Costs

The comparative costs with galena and ferrosilicon are given in Table XI. These show the ferrosilicon cost to be 12.09¢ per ton less than the cost would be with galena at this time. The largest reduction is in the cost of medium and reagents, which is 1.03¢ per ton as compared to 11.29¢ per ton with galena. The reduction in operating labor resulted from the curtailment of three men at the time of the conversion to ferrosilicon. Although there has been a decrease of 0.14 kw hr per ton in power consumption, or 6.8 pct, the cost of power has increased slightly since 1947 because of higher local distribution charges.

Summary

Conversion to ferrosilicon has reduced heavy media separation operating costs by 12.09¢ per ton, given an improved recovery and higher tonnage rate, increased the percentage of the mill feed rejected as a coarse tailing, and provided a relatively simple circuit that has turned out consistently good results under all feed conditions. Further improvements in metallurgy are anticipated now that the early experimental phases have passed and the operation has become established on a routine basis.

Acknowledgments

The writers wish to thank H. I. Young, President of the American Zinc, Lead & Smelting Co., for permission to publish the information contained in this report. The assistance of H. A. Coy, General Supt. of the American Zinc Co. of Tenn., and of Robert Ammon, Chief Metallurgist of the American Zinc, Lead & Smelting Co. is gratefully acknowledged. The fine work of John Hook of the Mascot Geological Dept., who took the photographs, is much appreciated. The authors are also indebted to E. W. Gieseke of the American Cyanamid Co. for his constructive criticism and many helpful suggestions.

Cyclone Thickeners, A Practical Solution for Closed Water Circuit Operation

by Victor Phillips and James P. Blair

Cyclone thickeners have emerged from the development stage and now can be accepted as useful tools for the recovery of fine coal from a preparation plant circulating water. As primary thickeners in a closed water circuit operation, their advantages over conventional thickening methods are twofold—the lower initial investment and reduced area requirements.

CLOSED water circuit operation at the coal preparation plant of the United States Steel Co., Clairton Works, has never been optional. Prohibited by law from disposing of slurry to the adjacent Monongahela River and prevented by lack of available space from utilizing settling ponds, it has been mandatory that the system operate on a closed water circuit or not operate at all.

Lyons[1] has outlined in detail the generally accepted concepts of closed water circuit operation the chief of which is that "no portion of either the operating water or of the fine solids removed from the operating water is allowed to drain or 'bleed' directly to a stream or natural water course." This is literally true at Clairton since there is no existing outlet whereby slurry could be bled to the river. Whenever it has been necessary to drain the system, a limited impounding area located at some distance from the washing plant is used. At such time as when the cleaning operations are to be resumed, the water is returned to the system for recirculation. As a result of these limiting circumstances, this Rheolaveur preparation plant, sealed discharge for coarse coal and free discharge for fine coal, has operated under a handicap.

Normally the operation is scheduled to be carried on for 40 hr without interruption with the subsequent 8-hr period devoted to service and repair of the washing equipment. Although it has been possible to adhere to this planned routine most of the time, it has been necessary on occasion to stop the 40-hr run because of an excessive build up of very fine solids in the circulating water. Since it has been established that there can be no plant bleed and consequently no addition of equivalent amounts of fresh water to dilute the system, stopping the washing of coal and taking time to clean out the heavy burden of solids are the operators' only alternatives.

Until recently, the water clarification equipment consisted of two 70-ft diam Dorr thickeners, which have been processing about 3000 to 4000 gpm of overflow from the fine coal boot and the fine coal settling tank. Installed with the cleaning plant in the early 1930's, these thickeners have given nearly 20 years of continuous service and have been relatively free of serious operating and maintenance difficulties. Concentrated slurry from these units was collected and pumped for further dewatering to a pair of Genter vacuum filters which had a combined filtering area of 1400 sq ft. Within the past few years a 40x60-in. solid bowl centrifugal filter was put into service to augment the original equipment. In both instances the effluents were returned to the clarified water sump for recirculation in the plant.

The settling areas of the thickeners and the capacities of the filters were adequate during the earlier days of operation. As the proportion of fine solids in the raw feed increased, as a result of mechanized mining methods, the load to the water clarification system grew. The situation became more critical until it was deemed necessary to provide additional solids recovery equipment to compensate for the increased load. Careful investigation of available equipment and a study of performance in the field indicated that cyclone thickeners in conjunction with a disk-type vacuum filter were a promising combination. In addition to the economical advantages of the proposed system, the relatively small space requirements for a cyclone thickener installation were considered attractive in view of the fact that available areas for conventional settling devices were so limited.

Although the original patents for cyclone type thickeners date back to 1891,[2] the principles of these patents only recently have been put in general use in the coal industry. Simplicity of construction and operation have been intriguing features to those who have investigated their potentialities. Basic construction for cyclone thickeners provides a tangential entry tube into a cylindrical section of appropriate diameter. Attached to the lower end of the cylindrical section is a conical portion tapering to a relatively small opening. At this apex the concentrated

V. PHILLIPS, Junior Member AIME, is Coal Preparation Engineer, with the Eastern Gas & Fuels, Associates, Pittsburgh. J. P. BLAIR, Junior Member AIME, is Coal Preparation Engineer with Heyl & Patterson, Inc., Pittsburgh.

Discussion on this paper, TP 3114F, may be sent to AIME before Sept. 28, 1951. Manuscript, April 6, 1951. St. Louis Meeting, February 1951.

Fig. 1—Bank of five 14-in. diam cyclone thickeners. Capacity of unit is 1500 gpm.

solids are collected and discharged. At the top of the cyclone a cover plate with a downward projecting tube, generally described as a vortex finder or overflow orifice, provides an exit for the clarified water. When fed under pressure, high force fields are developed within the cyclone thickeners with the result that even very fine solids can be settled rapidly. The separated solids which tend to accumulate at the outer walls are then forced to the apex by means of the tapered section.

After a comprehensive engineering study of the entire circulating water system at the expected peak load, the decision was made to install five 14-in. diam cyclone thickeners, shown in Fig. 1, together with five units of 3-in. diam cyclone thickeners, each unit containing 22 individual cyclones, shown in Fig. 2. Both sizes are standard units manufactured by Heyl and Patterson, Inc., Pittsburgh. In conjunction with these cyclones, a 12-disk, 8 ft 6 in. diam Oliver American vacuum filter was installed to accommodate the recovered thickener products. The revised flow scheme is shown in Fig. 3.

By utilizing a 32x32 ft space formerly occupied by a 500-ton storage bin, the Clairton Works engineering department was able to house the entire cyclone thickener and vacuum filter system without requiring additional structures. Built on three levels the cyclones are situated on the uppermost floor, the vacuum filter is on the second, while the centrifugal slurry pumps and the dry vacuum pump are neatly grouped on the ground level.

Inasmuch as the cyclone thickeners were to operate in parallel with the Dorr thickeners, a portion of the Dorr feed was taken to the 14-in. cyclones. Thus by lightening the solids and water load to the stationary thickeners more effective use of that equipment could be realized. Since the take-off point for the 14-in. cyclone feed was at the bottom of the Dorr feed launder, it was expected that stratification would result in a feed that was more concentrated. This was confirmed during a test run when the feed concentrations were determined to be 15.6 pct and 11.1 pct for the 14-in. cyclone and the Dorr thickeners, respectively.

Mounted as an integral unit, the five 14-in. cyclones flowing about 1500 gpm at 40 psi feed pressure simultaneously thicken and classify the feed slurry. By gravity, the thickened underflow is directed to the American filter for further dewatering. On occasion the underflow has been so dense that cyclone feed has been used as push water in the collecting trough, which has a slope of 1½ in. per ft. This extremely heavy underflow is most pronounced when the underflow orifices of the cyclones are new and unworn, thereby presenting a minimum passage to the flow of fluid yet allowing the concentrated solids to flow freely. The clarified overflow of the 14-in. cyclones flows to a screened sump for pumping to the 3-in. cyclones where further recovery of solids takes place. A dismantled 3-in. cyclone is shown in Fig. 4.

Table I indicates the performance of the 14-in. cyclone thickener during a 40-hr period, Oct. 15 to 17, 1950, approximately 6 weeks after the additional water clarification equipment had been installed.

The construction of the large diameter cyclone thickener is as follows:

The outer shell is fabricated steel with the inner surfaces of the cyclone body lined with a ½ in. thickness of soft, abrasion-resistant rubber vulcanized into position. Abrasion resistance is extremely important since the destructive action of slurries moving at relatively high velocities is well known. Although the body itself is not completely free from abrasion, the principal wear occurs at the apex where the concentrated slurry emerges. Regarding the rubber lining of the body it can be stated that careful inspection of the cyclones after more than 2500 hr of actual service revealed an almost negligible amount of wear. This can be attributed largely to the fact that the top size of the solids passing through the cyclones has been about 16 mesh. At other installations where coarser sizes are being processed, the wear rate is reported to be somewhat higher.

Fig. 2—Bank of 22 3-in. diam cones. Capacity of units is 250 gpm.

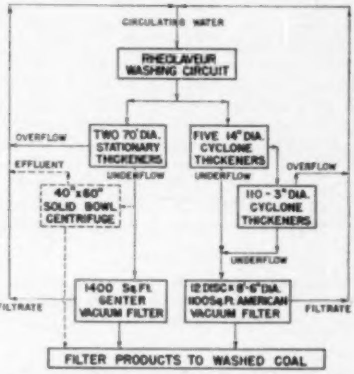


Fig. 3—Water clarification system, Clairton Works coal preparation plant, United States Steel Co.

To compensate for the abrasion at the lower end of the cone, the underflow orifice has been designed as a replaceable part. Held in position by an aluminum retainer, the orifice can be replaced quickly after removal of two bolts. Originally the orifice piece was an all-molded rubber section but later developments indicated that it was a more economical arrangement to provide a small nihard orifice piece at the very apex of the cyclone. Thus the rubber orifice piece has become the mounting for the metal insert. Although the inserts have had to be replaced on an average of about 200 hr at this installation, the rubber mounting pieces appear to have a useful life well in excess of 1000 hr.

Continuing with the circuit, the purpose of the screen over the 3-in. cyclone thickener feed sump is to scalp any oversize foreign objects such as wood chips or other light gravity solids that conceivably could have been rejected as 14-in. cyclone overflow. Accumulation of material on the screen surface has not been a problem since the percentage of trash is unusually small. It has been demonstrated that solids that pass the ⅛-in. diam round hole openings of the screen surface will also pass through the openings of the 3-in. cyclone without danger of plugging. Although there was some difficulty with plugging during the initial operation of the system, in all cases the trouble was directly traceable to oversize solids, such as weld spatter and small portions of welding rods, which inadvertently had been permitted to get into the piping system during the erection. Now that the system has been purged of this material no further plugging problems have presented themselves.

Table I. Performance Data for 14-in. Diam Cyclone Thickener, Feed Pressure 40 psi

Size, Mesh	Feed Wt, Pct	Feed Cum, Pct	Underflow Wt, Pct	Underflow Cum, Pct	Overflow Wt, Pct	Overflow Cum, Pct
16x28	6.0	6.0	8.0	8.0		
28x48	15.0	21.0	30.0	38.0	Trace	
48x100	11.5	32.5	24.5	62.5	Trace	
100x200	7.0	39.5	16.5	79.0	4.0	4.0
200x325	5.5	45.0	7.5	86.5	8.0	12.0
325x0	55.0	100.0	13.5	100.0	88.0	100.0
Solids, pct	15.6		48.8		9.0	
Ash content, pct	13.7		10.6		17.2	

Table II. Performance Data for 3-in. Diam Cyclone Thickener, Feed Pressure 40 psi

Size, Mesh	Feed Wt, Pct	Feed Cum, Pct	Underflow Wt, Pct	Underflow Cum, Pct	Overflow Wt, Pct	Overflow Cum, Pct
100x200	4.0	4.0	15.0	15.0	2.0	2.0
200x325	8.0	12.0	22.0	37.0	1.0	3.0
325x0	88.0	100.0	63.0	100.0	97.0	100.0
Solids, pct	9.0		32.7		6.8	
Ash content, pct	17.2		11.9		19.2	

Table III. Vacuum Filter Performance Data

	American	Genter
Area, sq ft	1100	1400
Cake rate, tons per hr	30	38.7
Feed (solids, pct)	43	36.6
Cake moisture, surface, wet basis, pct	24.8	26.8
Filtrate (solids, pct)	Trace	2.8
Ash content, pct		
Feed	11.1	11.6
Cake	11.1	10.3
Filtrate		14.4

From Table II it is evident that the 3-in. cyclone feed consists principally of solids smaller than 200 mesh, which explains the use of the smaller, higher efficiency units. Driessen and Criner[3] have established that the collecting efficiency of cyclone thickeners is an inverse function of cone diameter, i.e., large diameter cyclones make a 50 pct separation at a larger particle size than will a smaller diameter cyclone, see Fig. 5.

Concentrates from the 3-in. cyclones are added to 14-in. underflows, and the combined solids are dewatered on the American filter to form a cake having a moisture content ranging from 19 pct to 24 pct with the average being about 21 pct. Filtrate from this filter contained only a trace of solids, which results from using a closely woven fabric as a filtering medium. This is in contrast to the effluent of the Genter filters, which was 2.8 pct. In this instance a relatively open wire cloth was used as a filtering medium. Table III indicates the relative performance of the two types of filters.

Although it might be complained that there is a multiplicity of 3-in. cyclones, there being a total of 110 arranged in groups of 22, compact arrangement and other unique design features make for quick service and easy maintainance. Individual cyclones are of die cast aluminum and are equipped with removable rubber liners as well as replaceable underflow orifices. Again, for reasons of abrasion resistance, rubber has been utilized for these parts. How-

Fig. 4—Dismantled 3-in. diam cyclone.

ever, because the coarse solids have already been removed in the 14-in. cyclones, wearing of the 3-in. cyclone parts has been found to be very moderate. After more than 2500 hr of operation the original body liners are still in service and show only minor signs of abrasion. During this same period the rubber underflow orifices have been replaced twice, and the third set is still in service.

The clarified 3-in. cyclone thickener overflow is piped to the Dorr thickener overflow sump at which point the combined flows become the plant circulating water. At this point in the system the functions of the water clarification equipment end and their success or their failure becomes apparent.

Performance of this particular system has been such that the circulating water is maintained at substantially less than 10 pct solids concentration, whereas prior to the addition of the new facilities, 18 pct was considered to be an average condition. Furthermore, the reported figure of 18 pct represented a composite sample made up of small increments taken during the normal 40-hr operating period. The fluctuations that were once tolerated are now practically eliminated. Instead of a gradual build up of solids within the system, the combined facilities now remove the material at the rate at which it enters the circuit yet maintain a reasonably low level of circulating water concentration. Driessen and Criner[3] have given a complete explanation as to how it is possible to reach an equilibrium solids concentration in a system where there is recirculation of fine solids.

With this additional clarification equipment in service it has not been necessary to operate the horizontal type centrifugal filter, and it is hoped that at a later date only one of the two Genter vacuum filters will be required. Another operational improvement resulting from the installation of the cyclone system has been the reduction of shutting down time at the close of any operating period. A 2-hr cleanout period had been the practice in order that enough of the solids in the system would be removed so that the raking mechanism of the stationary thickeners could be stopped with the assurance that it could again be placed into motion. Since the residual backlog of slurry is now so much lower, only 15 min is required to purge the system.

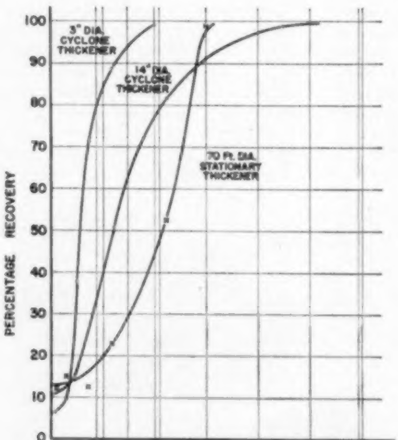


Fig. 5—Recovery characteristics, cyclone thickeners, and stationary thickeners.

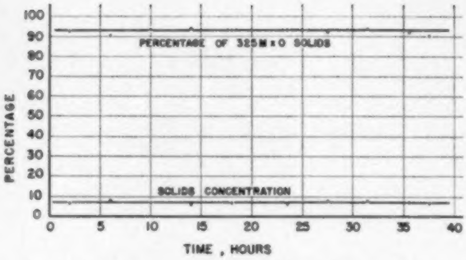


Fig. 6—Circulating water solids concentration and percentage of 325x0 solids during test period Oct. 15-17, 1950, Clairton Works coal preparation plant.

Uniformity of circulating water concentration is the hope of most preparation plant operators, but at Clairton it is a reality. Substantiating this statement are the analyses of samples of circulating water which were taken at frequent intervals during a 40-hr period. The results are shown in Fig. 6.

It is evident that the circulating water concentration remained within the narrow limits of 6 pct and 8 pct while the percentage of —325 mesh solids did not vary greatly from the 92.3 pct avg. That the percentage of 325 mesh x 0 solids as well as the solids concentration should remain nearly constant over a 40-hr period is most significant. It is factual evidence that the fine solids have not been building up without limit but rather have reached an equilibrium level, thus refuting the popular belief that recirculation of fine solids precludes the possibility of closing a water circuit.

Nearly 8 months of successful closed water circuit operation are now on the record as the result of this cyclone thickener-vacuum filter installation. Cyclone thickeners can no longer be considered laboratory novelties for they have emerged from this phase of their development and now must be accepted as a new and useful tool for fine coal recovery in the modern preparation plant.

Acknowledgment

The helpful assistance of L. F. Klingensmith, Superintendent, and R. R. Campbell, Assistant Superintendent, Coal and Coke Handling Dept., U. S. Steel Co., Clairton Works, in the preparation of this paper has been sincerely appreciated by the authors.

References

[1] O. R. Lyons: The Cyclone Thickener and Water Clarification in Coal Preparation Plants. *Mechanization*, December 1950.

[2] U. S. Patent No. 453105. May 26, 1891, Bretney.

[3] M. G. Driessen and H. E. Criner: Cyclone Thickener Applications in the Coal Industry. *Trans.* AIME (1950) **187**, p. 102; MINING ENGINEERING, January 1950, TP 2735.

[4] G. H. Kennedy and H. E. Criner: Applications of Cyclone Thickeners to Preparation Plant Water Circuits. *Trans.* AIME (1951) **190**, p. 259; MINING ENGINEERING, March 1951, TP 2991.

[5] H. F. Yancey and M. R. Geer: The Cyclone as a Thickener of Coal Slurry. *Trans.* AIME (1948) **177**, pp. 262-277; *Coal Technology* (February 1948) TP 2351.

Acid Drainage from Coal Mines

by S. A. Braley

THE first commercial production of bituminous coal in the United States was in 1820, and formation of acid in the areas from which the coal was removed began at that time. Tnus it is 130 years since the development of mine acid began. The coal operator has had to deal with the acid water produced in his mines, and his losses from corrosion of pumps and equipment have been tremendous. Other industries and the public have been forced to spend large amounts for their water requirements because of the acid discharge from the mines.

There are many contradictions in the literature on this subject probably because of variations in the analytical procedures followed and differences in the methods of calculation and reporting. The opinions previously expressed may be summarized as follows:

The production of mine acid has been looked upon as a simple chemical reaction wherein the oxygen of the air has reacted with pyrite to produce ferrous sulphate and free sulphuric acid. This reaction appears in many chemistry texts and generally has not been considered worthy of further study.

Since the measurement of hydrogen ion concentration or activity was developed and expressed in terms of pH, indicator and instrumental methods for pH determination have become readily available, making it natural to think of it as a measure of acid content.

Special purpose analytical methods applicable to potable waters, sewage effluents, and boiler waters, based in general upon the determination of what may be regarded as impurities, have been applied to more concentrated solutions constituting mine discharges, without reference to the fact that these specialized procedures had been developed to serve as operating guides for water-treatment plants.

It has been assumed that the pounds of acid delivered by a mine was roughly a constant varying with the number of acres mined, and that the concentration of the acid in the drainage was inversely proportional to the volume of flow. Increased flow was thought to result in a dilution of the acid produced.

Fig. 1—Change in rate of acid formation with decrease in oxygen concentration.

Table I. Showing pH and Titratable Acid of Varying Concentrations of Ferrous and Ferric Sulphates

Ferric Ion (Fe^{+++}) ppm	pH	Acidity ppm $CaCO_3$ equiv.	Ferrous Ion (Fe^{++}) ppm	pH	Acidity ppm $CaCO_3$ equiv.
11,200	1.80	30,000	11,200	3.98	20,000
5,600	2.01	15,000	5,600	4.15	10,000
2,800	2.21	7,500	2,800	4.41	5,000
1,120	2.48	3,000	1,400	4.68	2,500
560	2.60	1,500	140	5.00	250
280	2.65	750	28	5.50	50
112	2.81	300			
56	3.07	150			
28	3.38	75			

When the Sanitary Water Board of the Commonwealth of Pennsylvania established a fellowship at Mellon Institute, the first approach to the problem was to review some of the chemical reactions involved and their relation to acid production. Since the sulphates of iron were among the principal constituents of coal-mine drainage, the first studies were based upon solutions of chemically pure ferrous and ferric sulphate. These are both neutral salts, that is, the iron and the sulphate are equivalent, but they produce acid reactions in water solution because as salts of strong acids with weak bases, they hydrolyze to form acid solutions. Solutions of each salt, of varying concentrations, were prepared and the pH, titrable acidity and iron and sulphate

S. A. BRALEY is Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh.

Discussion on this paper, TP 3098F, may be sent to AIME by Sept. 28, 1951. Manuscript, Aug. 10, 1950. Charleston Meeting of the Central Appalachian Section, June 1950.

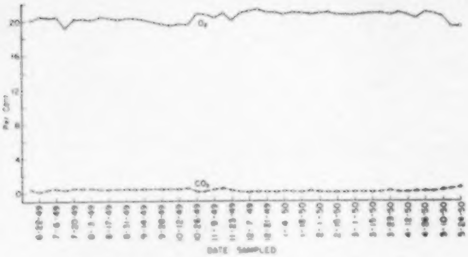


Fig. 2—Oxygen and carbon dioxide concentrations in Mine A for period sampled after sealing.

concentration determined for each solution. Titratable acidity was determined by titrating the hot solution to a phenolphthalein endpoint, using standardized sodium hydroxide solution, employing back titration with standard sulphuric acid when required. The data obtained are shown in Table I.

By definition, the pH of a solution represents the negative logarithm of the hydrogen ion concentration, the hydrogen ion concentration being expressed in terms of equivalents per liter. The hydrogen ion in these iron solutions is that derived from the ionization of the acid formed by hydrolysis of the iron salts, and both reactions are repressed by the buffer action of the unchanged salts present. During titration of such a solution with alkali, the pH (hydrogen ion concentration) remains practically unchanged until substantially all of the iron sulphates have entered into the reaction. Iron hydroxides precipitate and the liberated sulphuric acid is neutralized, causing the equilibrium to be maintained until neutralization is practically complete. As far as mine drainage is concerned, pH does not represent the titrable acidity, because the ferrous, ferric and aluminum sulphates, which are the principal acid-forming constituents of mine drainage, act as buffering salts.

A common source of sulphuric material in the coal mine is the so-called sulphur ball concretions found in the coal or in the banding rock. The sulphuritic material, which is found in the partings of the strata and disseminated through the associated measures as well as in the coal, is substantially of the same composition and is treated here as sulphur ball. Not all sulphur balls are actually sulphuritic. The sulphur balls that have been observed are about equally divided between those containing sulphuritic iron capable of producing sulphuric acid upon oxidation and those that are primarily calcium carbonate. It often is said that two mines on the same vein of coal separated by only a short distance produce different types of water, ranging from high acid on one side to high alkali on the other. This has also been found true in sections of the same mine.

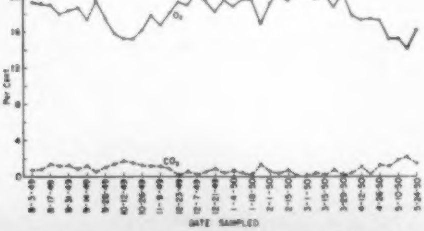


Fig. 3—Oxygen and carbon dioxide concentrations in Mine B concentrations for period sampled after sealing.

The points of entry of water into mines are difficult to find; in only a few cases could any exact point of entry be found. Whenever a point of entry has been found, the water coming from the undisturbed strata was alkaline rather than acid, a very good indication that the acid was produced within the confines of the mine. It was observed later that the amount of acid present in the water flowing or pumped from a mine represents that part of the acid production that has been permitted to come into contact with the transporting agency, the water, and is carried from the mine. When alkaline and acid water come from the same mine, a study of the geological strata and the condition of the section of the mines producing the different types of water usually will develop the answer to the question. If

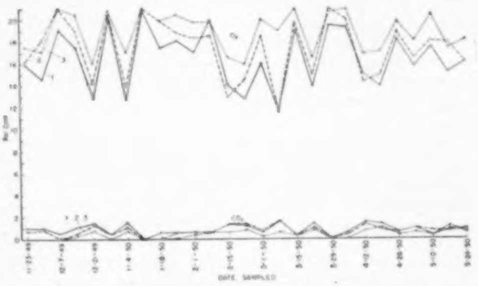


Fig. 4—Oxygen and carbon dioxide concentration of Mine C for period sampled after sealing. (1) 160 ft back of seal. (2) 120 ft back of seal. (3) 360 ft back of seal.

water entering the mine, like practically all ground water, is alkaline, that water, if it does not contact the coal face, the adjacent strata, or the products of their oxidation, will remain alkaline. Likewise, if no water enters the mine, no acid will be transported to the exterior regardless of the amount produced. Stream pollution by acid mine drainage is related directly to the water entering the mine, as the water must be contaminated before it can carry the contamination to the outside stream.

Study of a series of mines, with weekly sampling and gaging of their flow and complete analysis of each sample, indicated that the concentration of salts in the effluent from each mine was practically a constant for the mine, irrespective of season and flow, but the difference between two mines was often very great. This constancy of concentration for a given mine applies to ferrous and ferric iron, aluminum, calcium, magnesium, and sulphate. One point of extreme importance was the absence of free acid, that is, acid other than that produced by hydrolysis. This absence of free acid was determined by calculating the equivalents of the acidic constituents and equating them to the equivalents of basic constituents, the metals just referred to. From such an analysis the acidity of mine water may be determined in two ways, by calculating the equivalent of ferrous and ferric iron and aluminum,

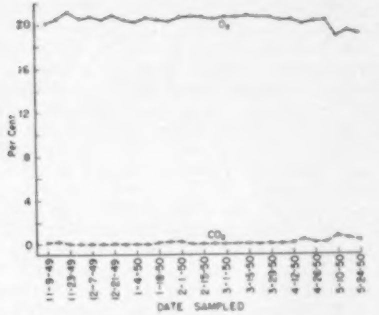


Fig. 5—Oxygen and carbon dioxide concentrations in Mine D for period sampled after sealing.

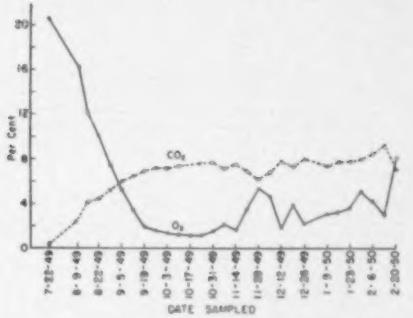


Fig. 6—Concentration of oxygen and carbon dioxide in Mine E for period sampled after sealing.

or by subtracting from the equivalents of sulphate the equivalents of calcium and magnesium. A few deep mines produce highly alkaline water with a chloride content as high as 1400 ppm. These waters are actually brines and fall outside of the scope of this discussion.

Theories have been advanced for the formation of acid as a result of bacterial activity. Those supporting this theory consider that some reaction other than normal chemical oxidation is necessary to explain the large quantities of acid produced. The results of Mellon bacteriological examinations are being reported elsewhere, but, thus far there is no evidence that bacterial activity plays an important role in acid formation. It is possible to credit chemical oxidation with all of the production of mine acid.

Rees and Kalinowski* reported that 10 to 12-in. cross-section samples representing the entire thickness of the coal seam of 14 different Illinois coals were stored in paraffin-coated boxes at 20 to 32°F for a period of 4½ years. During this time, under theoretically sealed conditions, the average increase in $SO_4^=$ content was 0.26 pct with a minimum of 0.05 pct and a maximum of 0.49 pct. This increase in $SO_4^=$ content may be considered as the equivalent of acid production, since it represents oxidation of the sulphur. This would represent a production of 316 lb of sulphuric acid a day, for the 4½-year period, from 100,000 tons of coal, stored in sealed containers. Thus, the acid produced by the oxidation of the sulphuritic material in pillar faces and gob remaining in a mine and openly exposed to air should be sufficient to account for all of the acid water draining from those mines.

The steps in the oxidation of sulphuritic material occurring in coal seams apparently are complex. Burke and Downs found that the reaction of dry air on dry sulphur ball material produced 1 mol of $FeSO_4$ and 1 mol of SO_2 for each mol of FeS_2 reacting. This has been confirmed, but it has been found further that in the presence of moisture the reaction produces 1 mol of $FeSO_4$ and 1 mol of H_2SO_4. Thus, one can assume that acid mine water should contain $FeSO_4$ and H_2SO_4. The water entering the mines has always been alkaline, with a definite concentration of alkaline salts of calcium, magnesium, and possibly sodium or potassium. The geologic strata in which the coal occurs contains shales and clays, together with certain amounts of calcite and limestone or dolomite, some capable of neutralizing the free acid, others being sulphuritic, all together producing a mine effluent consisting chiefly of the sulphates of ferrous iron, ferric iron, aluminum, calcium, and magnesium, and no free acid.

* Rees and Kalinowski: Trans. Ill. State Academy of Science. (1939) 32, No. 2, pp. 120-121.

The chemical oxidation of sulphuritic materials is indicated by the equations

$$FeS_2 + O_2 > FeSO_4 + SO_2$$

or

$$FeS_2 + 3\tfrac{1}{2}\, O_2 + H_2O > FeSO_4 + H_2SO_4$$

It would appear that the rate of oxidation, or acid production, should be proportional to the oxygen concentration and, consequently, proportional to the partial pressure of the oxygen. There may be, however, several intermediate reactions that occur during the process so that their relative speeds may alter the apparent conditions. The Ohio River Pollution Survey of the U. S. Public Health Service, (1942), presents a hypothetical curve to show the change in rate of acid production with the change in oxygen concentration. Because this was presented as a hypothetical curve, experiments have been conducted to determine the relationship between oxygen concentration and acid formation. The results are shown in Fig. 1.

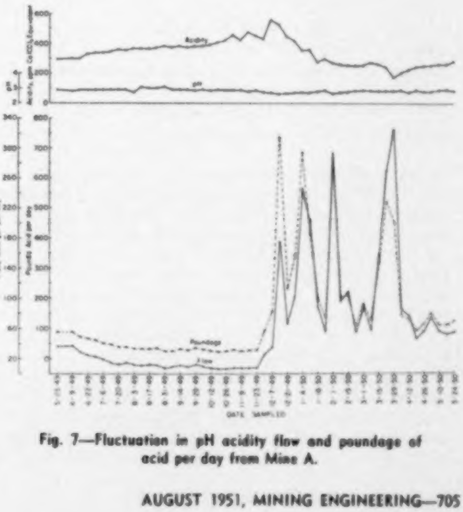


Fig. 7—Fluctuation in pH acidity flow and poundage of acid per day from Mine A.

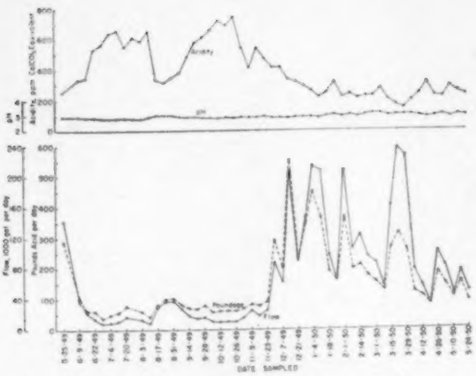


Fig. 8—Fluctuations in pH acidity flow and pounds of acid per day from Mine B.

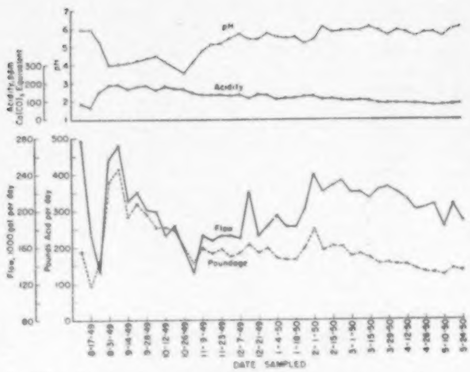


Fig. 9—Fluctuation in pH acidity flow and pounds of acid per day from Mine C.

This curve indicates the overall rate of reaction and acid formation with change of oxygen concentration. Pure air, 21 pct O_2 would produce 100 pct acid but zero oxygen, or air would produce zero acid, and a 15 pct oxygen concentration would be (12/21x100) 71 pct and produce 81.5 pct acid, or a reduction of 18.5 pct acid. Likewise 9 pct oxygen (9/21x100) 43 pct of 100 would produce 67 pct acid, a reduction of 33 pct. On the basis of the hypothetical curve, these reductions would be 40 pct and 92 pct, respectively. According to this experimental curve, exclusion of oxygen from a mine should reduce acid production. The decrease in the rate of acid production should be predictable from the reduction of oxygen concentration in the mine as determined from analyses of the mine atmosphere. To determine this, copper tubing was inserted through the stoppings in several sealed mines, so that atmosphere samples could be withdrawn from a point well back of the seal. Four of these mines were comparatively shallow-cover drift mines delivering acid water. The fifth was a shaft mine with a minimum of approximately 160 ft of cover. Samples

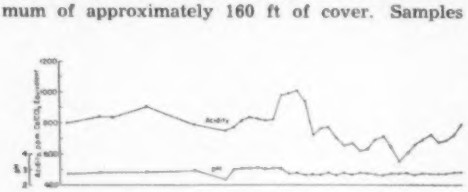


Fig. 10—Fluctuation in pH, acidity, flow and pounds of acid per day of Mine D.

were taken and analyzed by the customary gasometric method. The results are shown in Figs. 2 to 6.

It will be noted that there are fluctuations in oxygen content in most of the mines, but the maximum oxygen reduction in any of the drift mines is to about 11 pct, with frequent returns to substantially pure air, whereas in the shaft mine the oxygen decreased to 1.5 pct with a maximum of return to 8 pct. The observed oxygen content in the shaft mine is comparable to the oxygen percentages observed when deep mines are sealed to extinguish mine fires. It is not known whether such data have ever been obtained before on shallow-cover drift mines.

Mines A, B, C, and D were also intensively studied by weekly sampling of their discharges. These mines were comparatively small workings isolated from other mines, which eliminated possibilities of interconnection. They were mines that were long abandoned, and three of them had been sealed previously but no maintenance had been given the seals.

The drainage of these mines was sampled weekly regardless of weather conditions. Samples were taken in completely filled bottles that were kept below mine temperature, approximately 56°F, until subjected to analysis. Acidities were determined by titrating in hot solution to the phenolphthalein end point. Nearly neutral or alkaline waters were first acidified with standard sulphuric acid heated to boiling and back-titrated with standard alkali. The rate of flow from the mine was measured by means of a V-notch weir as the samples were taken for the total acidity and flow. From these two factors could be calculated the actual poundage of acid delivered by the mine to the receiving stream.

The mines on which no work had been done since abandonment were first dewatered by removing the entry stoppages caused by falls and cave-ins at the outcrop. The drainage then was sampled long enough to determine the effect of free flow. In the case of mines that had been sealed previously, the seals were removed and as much impounded water as possible drained out. These mines were then resealed, as was one of those that had never been sealed before. Figs. 7 to 10 illustrate the general activity pattern of these mines. They show the pH, acidity, flow, and pounds of acid delivered per day based upon regular weekly sampling, the samples being taken not only on the same day in each week

but at substantially the same hour. During the summer or low-flow period the acidity is slightly higher than during the later high-flow periods. The most striking factor is the relationship between flow and acid poundage. These curves parallel each other closely, indicating that acid delivery is almost directly proportional to flow, whereas the acid concentration or acidity, while showing considerable variation, is in a sense relatively constant.

The curve for mine A, Fig. 7, shows the beginning of increased flow on November 23. At this time the poundage and acidity also increased. On December 14 the flow reached a crest with a slight drop in acidity, but a tremendous increase in pounds of acid delivered. The amount actually delivered on November 23 was 30 lb, on December 14, 735 lb, an increase of 2350 pct, while the flow increased from 8000 gal to 175,000 gal, or 2087.5 pct. Furthermore, instead of the acid becoming diluted, its concentration increased from 425 to 525 or 23.5 pct. The next crest, on January 4, shows a decrease in acid poundage from the previous crest of 6 pct, with an increase in flow of 70 pct and a decrease in acidity of 33.3 pct. The third crest on February 1 shows a further increase in flow over January 4 of 19.2 pct, a decrease in acid poundage of 8 pct and a concentration decrease of 33.3 pct. This may be attributed to the flushing action of the high water, since it reached areas from which no water had been flowing over a period, and hence carried out acid produced but not delivered during the low flow periods. Intermittent flushing in this manner has the apparent effect of decreasing acid production. It should be noted that during all those fluctuations the pH remained almost constant, the variation being from 2.58 to 3.04, again demonstrating that pH measurement does not indicate many of the important properties of acid mine drainage.

The other mines follow the same pattern, the discrepancies being a difference in degree and not of kind. Since the flow is the most important effective variable, it is plotted on a single graph to illustrate the general pattern. The curve for mine D, Fig. 10, is erratic prior to November 4, as sealing operations were in progress and natural flow was impossible. Subsequent to this period, the four mines follow the same pattern of flow with the exception of mine C, which does not show a crest on December 14, but the increase in flow is gradual to the crest on January 4.

During the opening of mine B, Fig. 8, it was evident that large amounts of acid were being released, and since the receiving stream was stocked with trout and was at low flow, samples were taken to determine the effect on the stream and to stop the addition of the excess acid if a danger point was reached. This condition actually arose, and the flow of acid had to be halted to permit recovery of the stream, after which drainage was allowed to flow only at such a rate as to maintain the proper alkalinity in the stream.

The study of the effect of acid entering the stream was continued by means of weekly samplings to the completion of an annual cycle. The curves in Fig. 11 illustrate the results of this study on a pure mountain stream receiving the acid from two mines, A and B, described above. The curves represent the alkalinity of the stream at a point 6/10 of a mile above entry of the acid and 6/10 of a mile below the entry of the acid, and designated as before and after acid entry. The third curve represents the

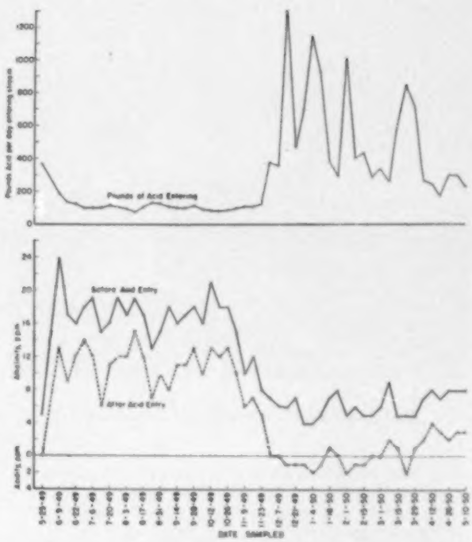


Fig. 11—Effect of acid delivered from Mines A and B on the receiving stream.

total pounds of acid per day entering the stream from mines A and B.

These data indicate a constant reduction of alkalinity of the stream irrespective of the amount of acid it receives. This may be explained by concurrent fluctuation of stream flow and mine discharge.

Also of note is the high alkalinity of the stream during the summer and fall months, the low-flow period, as compared with its alkalinity during the high-flow period, winter and spring.

Conclusions

1—Acid is produced by the oxidation of sulphuritic iron compounds in and associated with the coal measures. This reaction probably is a normal chemical reaction for which an equation can be written.

2—The amount of acid delivered by a mine is not the total amount produced in the mine but rather that accessible to the transporting agent, the volume of water flowing through the mine.

3—pH measurements in no way represent either the concentration or poundage of acid delivered or produced by a mine.

4—The delivery of acid from mines follows regular patterns, varying in degree and not in kind, when sampling intervals are short and are sufficiently continuous to establish the pattern. Since they deal with water flow that is dependent upon precipitation and ground water levels, they fluctuate with seasonal and daily precipitations. Annual, semiannual or quarterly sampling lead only to highly erroneous conclusions.

5—The production of mine acid is a process of nature, and while it operates on all coal measures and their associated strata, it is increased materially by any disturbance of geological formations that results in exposure of the reactive constituents to air and water.

The History and Development Of Phosphate Rock Mining

by R. B. Fuller

DURING the summer of 1949, the United Nations Scientific Conference on the Conservation and Utilization of Resources met at Lake Success. As summed up by one writer, the purpose was: "That everyone will try to learn how to feed more people from an acre of land." That objective is a stimulus to the phosphate rock industry as well as other industries.

Phosphate rock was mined first in the Canadian province of Quebec where it was found as an apatite in pockets. In 1863, mining began near the Rideau Canal, first in open trenches and quarries until shafts were sunk. These operations were difficult since hard rock had to be drilled and blasted. Steam was the source of power. The phosphate rock was hand-selected and recovery ranged from 6 to 10 pct, averaging 70 pct to 85 pct bpl (bone phosphate of lime). Costs, f.o.b. Montreal, were $14 a ton, and selling prices averaged $17 a ton. In 1885, about 29,000 tons were sold on this basis, but by 1892 the output fell to 8000 tons at an average price of $15 a ton at Montreal.

South Carolina Deposits

Phosphate rock was first discovered in South Carolina in 1837, but a mining company was not formed until 1867. It was immediately successful, and the industry continued to develop and ship an increased tonnage of land and river rock, shipments increasing from approximately 20,000 tons in 1868 to 537,000 tons in 1890, when the shipments began to decrease. In 1892 only 350,000 tons were shipped. In this field there were two types of deposits: land rock and river rock. More land rock tonnage was mined until about 1887 when river rock production began to equal it. The land rock was mined adjacent to and in the river marshes by pick, shovel, and wheelbarrow. Each worker dug daily a space 6 ft wide, 15 ft long and 6 ft deep, which was overburden, and then loaded about 3 cu yd of phosphate rock into wheelbarrows. His helper would wheel the barrows to small steam railroads up to 250 ft distant. Water was kept from the pits by steam pumps connected to railway cars.

The phosphate rock was loaded into railroad cars, hauled and dumped into a log washer to which water was added, and run over trommel screens to eliminate the clay and loose sand. Steam shovels for loading were introduced about 1891.

River rock was mined by floating dipper dredges and at low tide was loaded into barges by laborers using oyster tongs, the large lumps being hand-loaded. Barges and bateaus were unloaded by wheelbarrows which were wheeled to the same type of land rock washers. The washer product was piled with stacked pine cordwood in alternate layers and fired for drying. Usually this was done under sheds along the river bank. The dried rock then was transferred to ships, usually three or four-masted schooners.

Cost of production of both land and river rock, including $1 a ton royalty paid to the state for state-owned property, was approximately $4.25 a ton averaging 60 pct bpl. The selling price was approximately $7 a ton f.o.b. In 1886 the courts handed down a decision permitting anyone to mine, and many additional companies were organized immediately. As a result, the selling price was lowered to a profit margin of 50¢ or less per ton. The South Carolina mines were eventually shut down when a more profitable source of phosphate rock was discovered in Florida.

Florida Deposits

Phosphate rock was discovered in Florida in 1882, and in 1883 a small quarry was opened near Hawthorne. In 1886 phosphate rock of good grade was discovered on Peace River, and the Arcadia Phosphate Co. was formed. In 1888 the company began shipments amounting to 3000 tons that year. During the latter part of 1888, hard-rock phosphate was discovered near Dunnellon. Exploration extended rapidly, and deposits of hard-rock phosphate were mined over a wide area so that shortly after 1900

R. B. FULLER, Member AIME, is Manager, Phosphate Div., International Minerals and Chemical Corp., Mulberry, Fla.

Discussion on this paper, TP 3118H, may be sent to AIME before Sept. 28, 1951. Manuscript, Nov. 16, 1949; revision, Jan. 11, 1950. AIME Tampa Meeting, November 1949.

Fig. 1—The Bigger Digger, Bucyrus-Erie 1150-B dragline, 215-ft boom, 21.4-cu yd bucket.

Fig. 2—One of the first all-steel washers, 1928.

the census bureau reported 81 companies mining phosphate rock in Florida. Centrifugal pumps were used in the mining of Florida river pebble rock. They were 8 in. or 10 in. in size and were installed on a dredge with steam engines and boilers, which used wood as fuel. Alongside the dredge was a washer barge which had the usual trommel screen for discarding any tree roots or other foreign materials more than 1½ in. in size. Following the trommel were log washers and a rotary screen for rinsing. The washer rock was discharged by a chain drag into small barges, which were towed to the drying plant on shore and unloaded by shovels into an elevator or wheelbarrow. The rock was dried in 48-in. diam by 30 ft long rotary kilns using wood as fuel. The cost of dry river pebble loaded in railroad cars or lighters was reported to be $1.75 a ton, with a selling price equivalent to $5.50 a ton for 60 pct bpl.

About 1890, however, there was further activity at the headwaters of both the Peace and Alafia Rivers, and many new companies began mining principally in the creeks and shallow ponds adjacent to railroads. Thousands of acres originally sold as timber lands to Hamilton Disston by the state for 25¢ per acre were afterwards found to contain high-grade phosphate deposits.

Lower cost water transportation probably allowed the river pebble miners to compete so successfully with the South Carolina miners. The river pebble when dried on the lower extremities of Peace River was loaded into large lighters, which were towed to the entrance of Charlotte Harbor. The schooners had sheltered anchorage inside of the pass and would take on large portions of the cargo from the lighters with ship's crane. However, to get a full load the lighters and the ship were towed to deep water beyond the harbor where the cargo was transferred from lighters to ships, which delivered the cargoes both coastwise and to foreign ports. Eventually, a railroad was constructed from Arcadia to Punta Gorda and afterwards from Arcadia to Boca Grande.

Wood for fuel was becoming scarce and more expensive, and eventually some of the miners and the railroads brought in coal, and a coal storage dock was constructed at Boca Grande. About 1892, production in the United States was about evenly divided, approximately 350,000 tons each from South Carolina and Florida. Hard rock mining had been further developed in the northern and north central part of Florida. At first the rock was strip-mined, sorted by hand, and the selected lump phosphate dried in a pile on wood. The deposits were of a pocket type and did not occur in a blanket form over extensive areas as in the pebble field to the south. This was a lucrative business requiring little capital. The grade of rock was 80 pct bpl plus and was shipped mainly through Jacksonville and later through Fernandina.

Most of the capital for earlier pebble companies came from foreign sources. It was not until World War I that the French interests sold the last of their holdings because of the discovery of high-grade phosphate in Morocco.

The improvements in the hard-rock field followed the usual pattern. First, dredges were floated in pits and the excavated phosphate treated in log and screen washers. More fines were saved, but there was still a substantial loss. The washers were improved and the operations thoroughly mechanized, the fines being saved by tabling.

A central loading, storage, and drying plant was located at Fernandina, an export point until recently when a modern drying and storage unit was installed at Dunellon. Walking type draglines now handle the overburden efficiently.

With the exhaustion of river pebble deposits, which were placer deposits to a great extent, and the discovery in the Bartow-Mulberry area of more concentrated and higher grade deposits, many new mining companies were formed, which later were combined into a few. About this time electricity came into more general use.

Meanwhile a great many of the hard-rock pocket mines were mined out. Their costs were increasing so that by 1905 most Florida phosphate was mined in Polk County, or South Florida. Most creeks and shallow rivers had been dredged out, and the land pebble miners were forced to remove deeper overburden. This was started with mules and scrapes, and later when overburden up to 20 ft could be profitably removed, by steam shovels, dump cars, and steam locomotives. A great deal of overburden removal was contracted for at rates ranging from 12¢ to 25¢ per cu yd.

After the overburden of 15 to 20 ft had been re-

Fig. 3—Phosphate flotation plant constructed for recovering phosphate from formerly discarded washer debris.

moved, the matrix was sluiced with clear water to the suction of a 10-in. centrifugal pump by hydraulic giants operating at the rate of 2500 to 3000 gpm at a pressure of 125 lb. These centrifugal pumps were belt-driven by steam engines located 30 to 40 ft from the pumps; the boilers for the engines customarily were placed on top of the bank. The water for the hydraulic giants as well as for the washer was furnished by artesian wells 10 in. in diam sunk to depths varying from 300 to 600 ft. An air lift was used to get the water to the surface. The wells were located at central pumping stations and the triple-expansion, steam-driven plunger pumps or crank and flywheel pumps with fairly high vacuum had an initial pressure at the pump of 180 to 225 lb. However, in piping this water to the hydraulic giants, there was tremendous friction loss and a leak at practically every joint of pipe. Further developments in the centrifugal pump and the broadening of the use of electricity eventually eliminated some of these inefficiencies.

Several companies operated gas-producing engines using wood and coal as fuel, while others put in diesel engines. One installation had eight very large Busch-Sulzer diesel engine generators and Worthington-Snow diesel engine generators. At that time most of the phosphate companies were using wood as fuel for drying. One company used 600 cords of wood a day.

To meet the competitive prices of phosphate rock then prevailing, larger capital investments were required to lower the cost and make for a more continuous and uniform operation.

Where steam engines had formerly been used for operating the washers, the advent of electricity soon made a change, and motors were substituted from 1907-10. In practically all cases the motive power was transmitted to a central shaft and thence by means of counter shafts, gears, and bevel gears to the various moving parts of the washers. The general flowsheet of a phosphate rock washer was as follows:

The 10-in. centrifugal pump discharged the phosphate rock slurry through similar sized pipes to an entry box about 45 ft above the railroad track. The box had gates arranged to allow the mass of matrix containing 15 to 20 pct solids to pass onto sloping flat screens, which had staggered slotted openings of 3/64 x ½ to ¾ in. long, the surface area being governed by the percentage of solids in the matrix.

Large quantities of sand and disintegrated clay and fine phosphate rock particles escaped through the opening in the screens and went to waste with the water. The remainder of the material was swept into a horizontal trommel screen in which were inserted spiral flights for moving the +1½-in. material to a launder that carried these larger particles to waste. Under these trommel screens there was a similar screen which conveyed the material with additional clear water to customary log-type washers. From the washers the material went either to a shaking flat screen actuated by an eccentric or to rotary screens with the same size openings. It was customary to put this product through another set of log washers and then onto a dewatering screen before elevation into the bins under which cars were spotted for loading and shipping to the drying plants.

All the mining structures at that time were built of first-class pine and cypress timber, cut and manufactured from the area to be mined. Limited electrical power and the necessity for short pumping distances usually caused the mining plants to be located in the center of 200 to 240-acre deposits, which ordinarily were mined out in about 8 to 10 years. It was customary at the time for contracts to be written on the monthly average grade of the average analysis of the daily shipments. If waterborne, there were no particular stipulations as to the grade except a standard minimum, customarily 66 pct bpl, with premiums paid for excess grade.

Shortly after 1907, however, prospecting revealed that certain stratas in certain areas were consistent as to quality, and competition being more keen, contracts were made which specified minimum grades of 66, 70, 72, 75 and 77 pct bpl. About that time a more diligent search for high-grade possibilities was made by the existing companies and new companies then being formed. The steam turbine was introduced and proved a more economical and better source of electrical energy. New mines started up, which were entirely electrified except for the pressure pumps furnishing water to the mine.

Labor costs were $1.50 per 12-hr day. Many of the mines operated 24 hr a day, 6 days a week.

Another change in mining practices put into effect at this time was the hydraulic removal of overburden. This method required large vacant areas in which to impound the overburden and save the water for further use after clarifying. As later developed, it was unfortunate that a great deal of this overburden was dumped into the same areas that were also receiving the washer rejects. From then until World War I, both the Florida hard-rock and land pebble rock miners, in spite of keen competition, managed to survive and had practically put out of competition the South Carolina operators. Most of the high-grade Florida phosphate rock was exported and brought premium prices in Europe, South Africa, Australia, and New Zealand.

Improvements followed rapidly in Florida. Steam draglines replaced the hydraulic method in hard pan areas. Larger and more efficient draglines were developed, and finally the modern 21-cu yd machine, which greatly reduced stripping costs, was installed.

Mining methods were improved by moving the mine pump pit car out of mud and floods of pit bottom. The big dragline both stripped and mined the matrix and piled it in front of the pit car where it was washed into the suction sump with low pressure water. Before, high pressures of 200 psi or more mined the matrix from the face.

Fig. 4—1949 thickeners, flotation plant, conveyor system, and wet storage and drying facilities, Noralyn, Fla.

Immediately after World War I began, practically all of the operators in Florida shut down for several months, but when it became evident that the United States would be involved, the Department of Agriculture and those affiliated conducted an extensive educational program for greater crops. After World War I the producers of phosphate rock went into a depression because it was several years before definite plans were worked out for the rehabilitation of the soil of the devastated European countries. It then was realized that the Florida phosphate fields had lost a considerable portion of its foreign markets to producers in the Pacific and Indian Ocean Islands and that the new African deposits were becoming more extensively competitive in the European field.

During this time of curtailed activities, the companies that remained, about three hard rock and ten land pebble phosphate rock operations, did extensive research work with a view to making greater economies by increased use of electricity and by mechanical improvements. Two of these, the Bigger Digger, and one of the first all-steel washers, are shown in Figs. 2 and 3.

It was discovered that beneficiation by the flotation process could be adapted to waste products that consisted of large quantities of phosphate particles and that these fine sizes could be recovered economically. The first pilot flotation plant was constructed in 1927 by the predecessor of International Minerals and Chemical Corp. The application of the flotation process for recovery of phosphate is the most noteworthy achievement in the industry since phosphate rock was first mined on this continent.

At one mine the overburden had been stripped and hauled away in tram cars for a period of years, leaving a large mined-out area from which there had been recovered slightly less than 1 million tons of all pebble rock with an average grade of 75 pct bpl. The washer reject, or debris, was dumped into the mined-out pits adjacent to the washer without contamination with overburden. When the original washer had been abandoned, a flotation plant was constructed on the old washer site, and from this debris, which was pumped to the flotation plant with a floating dredge and centrifugal pumps, there were recovered over 1¼ million tons of 77 pct minimum bpl. A phosphate flotation plant constructed for recovering phosphate from formerly discarded washer debris is shown in Fig. 3.

However, flotation has made necessary much larger capital investments for the establishment of a mine and plant. It now has become necessary to make investments in the most up-to-date machinery and equipment and to increase in size and area any producing unit in order that profits may be realized and a higher grade produced and sold at prices comparable with the selling price 50 years ago. This has reduced the number of operations in Florida to one hard rock producer and eight land pebble rock companies. Today labor costs are more than four times what they were 20 years ago. Other items such as fuel, supplies, etc. have increased in price, yet even with technical developments, more labor has been employed. There is three times as much output per man hour as 20 years ago.

The greatest effect that the flotation process has had in the Florida field is to prolong the life expectancy of the industry and to increase the known

possible and probable reserves, thus warranting the increased capital investments. A modern flotation plant and conveyor system are shown in Fig. 3.

Through the next several years there no doubt will be scientific developments that will lead to further recoveries, extending the life of these deposits and causing an ever-increasing tonnage of phosphate rock to be shipped from Florida.

It is interesting that during World War II extensive shipments of phosphate rock were made from Florida to Buckingham, Quebec, which is within 30 miles of where phosphate rock was first mined on this continent. It seems significant that when the United States entered World War II, the initial attacks were made at points which quickly gave control of the phosphate deposits in North Africa and the Pacific Islands.

Tennessee Deposits

The Florida producers were confronted with competition in the domestic markets when in 1893 "blue" rock was discovered in Hickman County, Tenn.

Many blue rock mines were started, first to mine the accessible outcrops and then to follow the rather thin seams of 30 to 36 in. thickness underground, at increasing costs. One early mine at Toomey, well equipped with the then modern air drill, tram cars, crusher, and dryer survived a number of years but many other operations were unsuccessful. One operation at Gordonsburg operated very successfully until well into World War I. It was well equipped, and costs at first were quite reasonable, but thinning deposits that dropped lower in grade finally resulted in abandonment of the whole project.

White rock phosphate in Perry County had a similar history. The deposits were extremely spotty and erratic, but some high-grade phosphate was mined. During World War I, there was a brief revival of mining, but it could not survive competition.

Brown rock phosphate operations were started about 1896 in Maury and Giles County, Tennessee. At first, only select high-grade lump was stripped and mined by hand. The clay and fines were removed by hand screening or shaking out on a ten-tined potato fork. The lump was sometimes sun-dried on a "yard" or in bad weather stacked on layers of cord wood, which were burned to dry the phosphate.

About 1908–09 simple type washers followed by screens came into use to work the muck or underlying finer phosphate after the lump had been mined. Wood and coal-fired rotary driers replaced drying on wood for the fines.

About 1910 to 1911 progress started with the introduction of Dorr rake classifiers and thickeners for better washing and to save more of the fines. Hydroseparators followed Allen cones.

Among the Tennessee firsts was the use of a wet cyclone in 1923 and the first research on Tennessee phosphate flotation in 1927. Steam shovels were tried early in Tennessee, but the dragline introduced in 1914 gradually replaced mule scrapers and the like. Steam tram line transportation along with mule team haulage survived until about 1941, when the mule team faded from the scene, and as the larger blanket deposits were mined out, the truck took over haulage from the mines. The diesel dragline replaced the slower steam machine.

About 1936, the Tennessee high-grade deposits were being rapidly exhausted. At the present time little so-called acidulating or high grade, now 70 pct bpl, is being produced, but two factors came in to maintain Tennessee's second place in domestic production.

The consumption of 65 pct bpl phosphate for ground rock for direct application increased, and demand for electric furnace feed of still lower grade grew rapidly.

Now phosphate as low as 55 pct bpl is electric furnace feed; this permits the use of almost all the remaining reserves with blending and beneficiation by washing or similar treatment. There are many years ahead for the Tennessee phosphate industry.

Western Phosphate Reserves

Since recognition of phosphate in the West near LaPlata, Utah, in 1889, many enterprises have been launched, especially during World War I. Several underground mines were opened along with plants for crushing, drying, and grinding. After the war cheap water rates from Florida to the West Coast were restored. Florida captured much of the Western phosphate market and caused some of these early operations to shut down. Western phosphate reserves are largely in steeply dipping underground deposits of lower grade than Florida high-grade pebble. When conditions are favorable, it is possible to obtain a mining cost of $2.50 to $3 a ton, but more often the costs will be much higher.

The Anaconda Copper Co. has a successful mine in the West producing 68 bpl rock by top slicing in a fairly thick vein. The rock is crushed, dried, and shipped to Anaconda for producing triple superphosphate with the use of byproduct sulphuric acid.

There is another active underground operation near Garrison, Mont., where the output goes to Trial, B. C.

At Sage, Wyo., and Hall, Idaho, there are two strip mines where phosphate rock is being produced in considerable tonnage at very reasonable cost to supply the West Coast demand for fertilizer and for electric furnace operations at Pocatella, Idaho.

Some of the largest known reserves of phosphate rock are in Montana, Idaho, Wyoming, and Utah, and these deposits will be increasingly exploited with the expanding demand in the West for plant food.

From the Bureau of Mines, United States Department of the Interior, Minéral Market Report No. 1761:

"A new high record was made in the mine production of phosphate rock in the United States in 1948, according to reports submitted by the producers to the Bureau of Mines, United States Department of the Interior, the total reaching 9,388,160 long tons, more than quarter of a million above the 1947 record high. Of this, 7,184,297 tons were mined in Florida, over 800,000 tons greater than in 1947; 1,499,547 tons in Tennessee, only slightly more than in 1947; and only 704,316 tons in the Western States, about half a million tons less than in the previous year."

The average value of the phosphate rock sold during the first half of 1948 was $5.70 per long ton.

Scientists are conducting experiments which no doubt will lead to more efficient and more widespread use of phosphate compounds.

For the present there are two principal problems that warrant careful and immediate study and correction: 1—Cheaper power and 2—a lowering of the cost of distribution of the Florida phosphate rock. Florida has a bountiful supply and the world needs ever-increasing quantities.

AIME OFFICERS
Willis McG. Peirce, President
Vice Presidents
A. B. Kinzel Philip Kraft R. W. Thomas
J. L. Gillson M. L. Haider
Vice President and Treasurer
Andrew Fletcher
AIME STAFF
E. H. Robie, Secretary
E. J. Kennedy, Jr., Asst. Secy. Ernest Kirkendall, Asst. Secy.
J. B. Alford, Asst. Secy.
H. N. Appleton, Asst. to Secy. H. A. Maloney, Asst. Treas.
John V. Beall, Eastern Secretary, Mining Branch
R. E. O'Brien, Western Secretary, Mining Branch
808 Newhouse Bldg., Salt Lake City

AIME Board to Vote on Bylaw Changes at Sept. 12 Meeting

THE following amendments to the bylaws of the AIME were considered by the Board of Directors at its meeting on June 13, and are published preliminary to a vote thereon at the meeting of the Board on Sept. 12:

1. *To standardize the dues of Student Associates, allowing each a subscription to a monthly journal:*

Amend Art. I, Sec. 8, as follows by deleting the italicized words in the second sentence: "A full-time student in good standing in an approved school, who has been nominated by at least three instructors of the nominee (one of whom must be an Institute member), may affiliate with the Institute as a Student Associate by payment of $4.50 annual fee, for which he shall receive a subscription to one monthly journal and be privileged to attend meetings of the Institute and to use the Engineering Societies Library and the Personnel Service; *provided, however, that for Student Associates who do not elect to receive a monthly journal, the annual fee shall be $2.*"

2. *To provide for a credit of $2 on the initiation fee for each year of enrollment as a Student Associate or Junior Member:*

Amend the first sentence of Art. II, Sec. 1, by adding the italicized words in the following: "Each newly-elected Member or Associate Member, and each Junior Member at the time of his transfer into the class of Member or Associate Member, shall pay, immediately upon notification of such election or such transfer, an initiation fee of $20; provided, however, that said initiation fee may be payable, at the option of the applicant, in four equal annual installments, the first of which shall be due upon notification of election or transfer; *and provided further that, beginning Jan. 1, 1952, a credit of $2 towards the initiation fee be granted for each year up to ten of uninterrupted and continuing membership as a Student Associate or Junior Member, or both. When such credit is allowed, no installment payments of the initiation fee shall be granted.*"

3. *The following changes, to take effect at the annual business meeting, February 1952, are made necessary by the revised procedure of the Nominating Committee in naming a President-Elect instead of a President.* (Currently there is a transition period in which both a President and President-elect are being named for 1952.)

Amend Art. VI, Sec. 1, para. 1 and 2, to read as follows: "The number of Directors of this Corporation is 27, consisting of one President, one President-elect, one Past President, six Vice-Presidents, and 18 other Directors, to be elected as hereinafter provided; and in addition the Chairman of each duly constituted professional Division of the Institute, ex officio, shall serve as a Director, with full voting power, during his term as Chairman.

"At the regular November meeting of the Board of Directors or Executive Committee, the chairman thereof shall declare to be elected, as provided in Article XI of these Bylaws, nine Directors, of whom one shall also be designated as President-elect, and of whom two shall be designated as Vice-President. The nine Directors, including the Directors designated as officers, together with the newly elected Division Chairmen in their capacity as ex-officio Directors, shall take office at the annual business meeting of the Institute next following the meeting at which they were declared elected. The term of all nine elected Directors shall be for a period of three years; provided, however, that the terms of the President-elect and President shall each be for one year, the President thereupon serving one year as Past-President."

Amend Art. VI, Sec. 2, para. 1, (sentences 2 and 3), to read as follows: "The President shall be that Director who, in the preceding year, served as President-elect. The President shall be ineligible to hold that office again until two years after the expiration of his term as President."

Amend Art. VI, Sec. 3, to read as follows: "In the event of a vacancy occurring in the Board of Directors by death, resignation, promotion by election as President, President-elect, or Vice-President, or for any other reason than retirement at the end of three years' service, the remaining members of the Board shall elect a successor to fill the vacancy and to serve for the unexpired term. A member of the Board whose term has not expired and who is elected President-elect or Vice-President at an annual election shall be considered to have vacated his former office, and the Board shall fill the vacancy as above provided."

A proposed change in Art. I, Sec. 5, (sentence 2) clarifies the meaning formerly expressed: "He shall not have passed his 30th birthday anniversary at the time his application is received, and shall not remain a Junior Member beyond his 33rd birthday anniversary, except that the Board of Directors shall have the power to waive the age limitation in the case of veterans from military service." Omit: "(This last requirement shall take effect Jan. 1, 1950)" as obsolete.

A proposed change in Art. VI, Sec. 5, (sentence 2) recognizes the new office of Controller, approved by the Board at its meeting on Feb. 12, 1950: "Also, the Board may, upon nomination by the Treasurer, appoint one or more persons to perform the duties of Assistant Treasurer and of Controller."

A proposed change in Art. VIII, Sec. 2, para. 3, (sentence 5) sets a more practical time for the Board to pass on the final annual budget: "The Directors shall pass on this budget at their first open meeting after the annual business meeting of the Institute, modifying it as they consider necessary, and make

definite detailed appropriations for the current calendar year."

A proposed change in Art. VIII, Sec. 4, (sentence 1) eliminates the requirement that the Admissions Committee be limited to eight members: "The Committee on Admissions shall consist of at least eight members of the Institute, the chairman and at least one other member being chosen from the Board of Directors, and shall be appointed by the Board, on recommendation of the President, at the first meeting of the Board after the annual business meeting of the Institute."

A proposed change in Art. IX, Sec. 1, eliminates the second sentence, as no longer applicable. It reads: "In 1951 the Nominating Committee shall also select, as one of the nine Directors, a President to take office in February, 1952."

A proposed change in Art. IX, Sec. 2, para. 2, (sentences 4 and 5) eliminates a provision in the current bylaws that did not prove practical but maintains its intent: "In selecting candidates the Committee shall be guided by such rules of procedure as may from time to time be established by the Board; provided, however, that of the eight Directors in addition to the President-elect, a sufficient number be selected on the basis of geographical districts so that each such district will have at least one representative. The basis of selection of the others shall be at the discretion of the Committee."

A proposed change in Art. XI, Sec. 4, para. 3, 4, and 5, eliminates the requirement that Student Chapter officers, Faculty Sponsors, and Counselors all be required to make annual written reports to the Board:

"Each Student Chapter at its annual election shall choose an AIME member to be its Faculty Sponsor and forward his acceptance to the Secretary of the Institute. It shall be the duty of the Faculty Sponsor to promote the best interests of both the Student Chapter and the Institute and to make written reports of his stewardship to the Directors of the Institute as desired.

"It shall be the duty of the President of the Student Chapter and its Faculty Sponsor to secure, through the Local Section in whose territory it is situated, the appointment of a member of the Institute in the practicing profession to serve as Counselor for the Student Chapter, and to forward his acceptance to the Secretary of the Institute. It shall be the duty of this Counselor to promote cordial relations between the practicing engineers and the Student Chapter and to make written reports of his stewardship to the Directors of the Institute as desired.

"It shall be the duty of each Student Chapter to report promptly to the Secretary of the Institute the results of elections of officers, and to make written reports of activities to the Directors of the Institute as desired."

Opinions of AIME members on these proposed changes are invited and will be submitted to the Board before voting on Sept. 12. A copy of the current bylaws will be sent to any AIME member on request.

EJC Releases Bulletin On Selective Service Deferment Methods for Engineers

Bulletin 1 of the Engineering Manpower Commission of Engineers Joint Council, entitled "Utilizing Engineering Manpower . . . Deferment Procedures," was issued early in May. It is a 14-p. pamphlet discussing the selection and utilization of technical personnel, special Selective Service procedure pertaining to college students and current college graduates, general occupational deferment procedures under Selective Service for non-reservists, recall of reservists to active duty; and giving other pertinent information for engineering employers and employees. Copies have been supplied to all Local Section Secretaries, or will be supplied at 25c each on individual order to Engineering Manpower Commission, 11th floor, 29 W. 39th St., New York 18.

AIME To Release Three Books

Three special volumes to be published within the next year or two by the AIME under the sponsorship of the Seeley W. Mudd Memorial Fund and the Henry L. Doherty Memorial Fund have been authorized. The first of these, now in galley form, will be the second edition of *"Basic Open Hearth Steelmaking,"* which should be available within a few months. The second to appear will undoubtedly be *"Petroleum Conservation,"* edited by Stuart E. Buckley, the manuscript of which is completed. This is sponsored by the Doherty Fund. Third is a new edition of *"The Marketing of Metals and Minerals,"* a book first published a quarter century ago which has long been out of print. F. E. Wormser, one of the original authors and now vice-president of the St. Joseph Lead Co., and Simon D. Strauss, vice-president of the American Smelting & Authorization to proceed with the work was voted at the meeting of the Board of Directors on Apr. 18.

Board Meeting Date Changed

The December meeting of the Board of Directors, AIME, in New York will be held on Dec. 5 instead of Dec. 12, as previously announced. An extra meeting of the Board has also been scheduled for Los Angeles in the week of the meetings of the American Mining Congress and of the Southern California Section. The date will probably be Oct. 25.

Pan-American Engineers Adopt Constitution at Havana Meeting

Pan-American Union of Engineering Societies (UPADI) held a meeting in Havana, Cuba, Apr. 19 to 22, to adopt a constitution for its operation. AIME representatives F. T. Agthe and W. H. Carson were among the Engineers Joint Council delegates representing engineering societies of the United States. The 59 delegates from 19 nations spoke for 165,000 engineers, of which EJC represented 125,000.

A provisional constitution was approved that will be in force until the next UPADI meeting in New Orleans in 1953. The aims of UPADI, as stated in the constitution are to encourage, promote, expand, and guide the work of engineers in the Americas. It will hold periodic Pan-American engineering congresses and expositions that will promote individual and collective visits between member countries and to other places of interest; interchange of teachers, lecturers, engineers, and students between schools and engineering associations; and personal contacts between engineers of different countries.

In addition, UPADI will organize and develop relations between engineering organizations on an administrative level; technical, professional, economic, and social interchange, either individually or collectively, among the members of the constituent organizations; technical competitions among the engineers and engineering students of the Americas; professional rules of practice; and application of professional codes of ethics. It will promote the study of technical problems which jointly affect member countries, and inter-American public works and economic problems.

UPADI aims to contribute to the enhancement of the status of the engineering profession; increased usefulness of the profession to the public; strengthening the cause of peace and the ties between nations; closer technical relations between American countries; and economic development of American countries.

Each country will be represented by only one member. Financing will be through a separate permanent agency that will collect, deposit, and control donations, bequests, subsidies, or grants. Chairmen of each of the four committees organized were representatives of Engineers Joint Council.

Plans Underway

For AIME Fall Meeting In

MEXICO CITY!

NO fall meeting of the Institute in years has aroused the interest already shown in that to be held in Mexico City in the week beginning Oct. 29—the 172nd national meeting of the AIME. A substantial contingent even of metals and petroleum members seems likely, even though these groups are not participating in the technical sessions.

The Minerals Beneficiation Div. members will be out in force, attracted by a program of four technical sessions plus a luncheon and the traditional Scotch breakfast, which has been converted by Mexican trimmings to a Rancheros breakfast. The Tuesday morning session, covering Mexican milling operations, will represent four of the largest operations in Mexico, covering production of lead, zinc, copper, and silver. It is expected that written discussion of each paper will bring out sidelights on similar operations at other places. The papers are: (1) *Lead-copper Separation Processes at the Fresnillo Corp.*, by C. J. Veale, mill superintendent; (2) *Application of Pre-flotation to Cyanidation Ores at Real del Monte y Pachuca*, by R. R. Bryan, general superintendent of mills; (3 and 4) *Effect of Zinc Deleading Operations of Lead-Zinc Selectivity at the Parral and Santa Barbara Units of the American Smelting & Refining Co.*, by C. L. Boeke and C. G. Gunther, respective mill superintendents.

MBD's Tuesday afternoon session will cover typical installations of aerial tramways and belt conveyors, and will compare the operating characteristics, capital cost, and operating cost. The Wednesday morning session will be devoted to grinding and classification. In spite of all of the research which has been done on comminution and in spite of the relatively high cost of crushing and grinding, few of the fundamentals have yet been agreed upon. Therefore, the three papers for this session should be particularly interesting. They are: (1) *Development of the Use of Screened Ore for Fine Grinding at Lake Shore Mines*, by B. S. Crocker, mill superintendent; (2) *Three Theories of Comminution*, by Fred Bond, Allis-Chalmers Mfg. Co.; and (3) *Classification*, by H. W. Hitzrot, Dorr Co. Wednesday morning's milling sessions will be followed by a luncheon and business meeting and then an informal seminar on milling and a cleanup session.

All three groups in the Mining, Geology, and Geophysical Div. are developing programs. The Mining Subdivision is holding one session alone and one joint session with the Geology Subdivision. For the mining session the following papers are scheduled: (1) *San Antonio Mines, Santa Eulalia, Chihuahua*, by C. M. Syner, general superintendent, and W. P. Hewitt, geologist, Santa Eulalia Unit; (2) *Mexico's Thousands of Independent Miners—the Gambusinos*, by R. M. Attwater, Jr., consulting engineer and G. W. Jarman, Jr., president, Separations Engineering Corp. There will also be a paper on operations of the Braden Copper Co., Chile.

At the joint mining and geology session three papers have been scheduled to date: (1) *Organization and Policies of the Atomic Energy Commission*, by Jesse C. Johnson, director, raw materials AEC; (2) *General Policy on Raw Materials for Atomic Energy*, by W. J. Bennett, president and general manager, Eldorado Mining & Refining Ltd., and (3) *Geology and Mineral Deposits of Mexico*, by T. P. Clendenin, chief geologist of AS&R. One paper is at present scheduled for the geology session: *Correlation of the Sedimentary Section at Cananea with the Section in Southern Arizona*, by Ruben Velasco and Roland B. Mulchay.

No details of the Industrial Minerals Div. or the Mineral Industry Education Div. programs are available yet.

The social events and the general arrangements for the meeting were covered in the July issue of MINING ENGINEERING, pp. 620 and 621. A booklet about the meeting is being printed in Mexico City and shortly will be mailed to all who write in expressing an interest in the meeting. Address Mr. William G. Kane, San Juan de Letran 9, Room 805, Mexico D.F., Mexico. Fill in the coupon below if you are fairly certain of going.

For those who plan to drive to Mexico City from Laredo, a geological road log is available, prepared for the field trip of the South Texas Section of the AAPG which went to Mexico City in October 1948. Copies will be supplied on request to the Secretary, AIME, 29 W. 39th St., New York 18, N. Y., and will be mailed about Sept. 1 to those who ask for them.

From El Paso, motorists may take the Central Highway, through Chihuahua (227 miles), Ciudad Camargo (332 mi.), Hidalgo del Parral (423 mi.), Durango (680 mi.), Fresnillo (828 mi.), Zacatecas (866 mi.), Aguas-

calientes (947 mi.), Leon (1021 mi.), [short side trip to Guanajuato if desired, Queretaro (1132 mi.),] Toluca (1247 mi.), to Mexico City (1287 mi.). This is all hard-surfaced highway, and most of it through desert country. It is longer and not as scenic as the road from Laredo, but can be traveled at higher speed.

At Xochimilco, a suburb of Mexico City, natives and tourists drift through the Chinampas, or Floating Gardens.

From Laredo one drives to Monterrey (145 mi.), Ciudad Victoria (320 mi.), Tamazunchale (527 mi.), to Mexico City (750 mi.).

American Airlines issues an interesting little booklet, "In Mexico It's the Custom, Senor!", which any visitor, whether going by air or not, will find informative. Write American Airlines Inc., 100 Park Ave., New York 17, or American Airlines de Mexico, S. A., Avenida Ejido No. 7, Mexico, D.F. Special round-trip excursion fares are available and your family can come with you for half-fare if you travel on Monday, Tuesday, or Wednesday. Tell American when and where you want to go and they will tell you the cost.

Special railroad cars may be provided if there is sufficient demand. A special train is not suggested, for usually inferior equipment is used, whereas modern equipment is available on some of the regular trains, particularly on the Missouri Pacific's streamliner from St. Louis.

Mr. William G. Kane
San Juan de Letran 9, Room 805
Mexico, 1, D.F.

Please make the following reservations for me for the October meeting:
Single Room .... Double Room with twin .... double .... beds, at about $............. per day. (Single, $3.50 to $8; double, $4.50 to $8.50.) There will be .... men and .... ladies in my party.
Expected date of arrival ....; departure ....
Coming via motor ....; air ....; rail ....

Name ....

Title and Company ....

Street ....

City, Zone, State Me8

Junior Members To Get $2 A Year Credit On Initiation Fee

To make it easier for Junior Members to change their status to Associate Member or Member upon reaching the age of 33, or earlier if they so wish, the AIME Board of Directors, at its meeting on June 13, proposed a change in the bylaws to grant a credit on the prescribed initiation fee of $20. For each year of continuous enrollment as a Student Associate or Junior Member immediately preceding change of status, a credit of $2 is planned. Thus, if a young man is a Student Associate for two years, followed by eight or more years as a Junior Member, he will have no initiation fee whatever to pay. This should make it possible for a large number of Junior Members, who have found the financial handicap difficult even though allowed to pay the initiation fee in four $5 annual installments, to continue their affiliation with their professional society. It will also be an excellent argument for continuing as a Junior Member following graduation from college.

The plan involves a change in the bylaws, action on which is planned at the Sept. 12 meeting of the Board. It is expected to go into effect Jan. 1, 1952; that is, those who are forced to change status at the end of 1951 may receive the stated credit, as will those who are not yet 33 but who apply for a change of status to be effective Jan. 1, 1952.

In view of the above $2 credit, the special rate of $2 per year for Student Associates who do not receive a subscription to a monthly journal would be eliminated. A comparatively small number of Student Associates are in the $2 class, the vast majority paying $4.50 and receiving a journal. Final decision on this, also, will be made at the Sept. 12 meeting of the Board, when a vote will be taken on the bylaw change.

Half Year Financial Report Indicates AIME Surplus for 1951

Income of the AIME for the first six months of 1951 shows an increase of $28,405 from the same period in 1950, and expenses have been $10,200 less than a year ago. The net improvement is thus $38,605. Inasmuch as the Institute wound up the year 1950 with a deficit of $14,854 it would appear from present indications that for the first time since 1942 the AIME will end the year with a surplus without tapping any special fund. The improvement over last year is better than the figures indicate because the expense of the Salt Lake City office of the Mining Branch is being taken out of regular income, whereas last year it was met by special appropriations.

Income from dues and initiation fees in the first six months of 1951 totaled $279,173, compared with $269,776 in 1950; advertising, $67,430 ($51,163 in 1950); publication sales, $37,131 ($35,351 in 1950); other income, $5,361 ($4,397 in 1950); total, $389,094 ($360,689 in 1950). Expense for Local Sections, Divisions, and Meetings was $46,187 ($36,576 in 1950); library assessment and building rental, $9,867 ($12,362 in 1950); publications, $150,454 ($166,726 in 1950); general and administrative, $50,424; ($51,589 in 1950); total, $257,784 ($267,984 in 1950).

To Study AIME Methods

Herbert H. Vasoll, a partner in the firm of Davies & Davies, New York, has been retained to make a study of AIME office procedures. The aim is to have an outside expert with a knowledge of the latest in office methods and equipment suggest any changes that would lead to increased efficiency or lower costs, or both. His report to the Board should be made early in the Fall.

ASCE to Mark 100th Anniversary With 1952 Centennial of Engineering

In celebration of the 100th anniversary of the American Society of Civil Engineers, a Centennial of Engineering will be held from Sept. 3 to 13, 1952. There will be 1—An international Convocation of engineers in Chicago, 2—An Exposition centering around the Museum of Science and Industry at Chicago, and 3—Carefully prepared literature, moving pictures, radio and television productions. The Convocation should prove to be the greatest gathering of engineers of all time. Many American and foreign engineering societies, including AIME, and international organizations will participate. The greatest single event will be an international banquet meeting on Sept. 10, 1952.

The Exposition will follow the general pattern of permanent exhibits of the Museum of Science and Industry and will not be the general trade show where manufacturers and equipment dealers display their products. The exhibits will be dynamic in character and designed to impress upon the mind the basic principles of science and engineering. The Centennial is planning to install appropriate exhibits in the various major fields of engineering, and will be open to the public in July 1952. In addition, a dramatic pageant built around the accomplishments of engineering will be presented daily during July, August, and September in the 1000-seat auditorium at the Museum. The aim is to awaken the public, particularly young people, to the fundamental reasons why the United States has reached its preeminent position among the nations of the world and to the significant role engineering has played in bringing the country to that position.

Engineering societies participating will hold meetings during the Centennial, and where engineering activities of several societies permit, joint meetings may be held. While there will be a great percentage of papers of a high technical nature on the programs of the societies, it is expected that a substantial number of sessions will be of sufficiently broad interest to attract both engineers and the general public.

To furnish general direction for the $1,000,000 program and to be specifically responsible for all phases of the Exposition and the production of technical and non-technical literature, Centennial of Engineering, 1952, Inc., a non-profit corporation, has been formed. Each society participating in the Convocation will meet the expenses that normally would accrue to its meeting. Formal requests have been made for a postage stamp to commemorate the Centennial of ASCE in 1952.

W. McG. Peirce is Guest At July Anthracite Section Meeting

AIME President Peirce was the guest of honor at the summer meeting of the Pennsylvania Anthracite Section held at the Scranton Country Club, Pa., on July 9. Mr. Peirce said that each year the Institute administration sets certain objectives for the year and that this year it was greater efficiency in New York office procedure. Progress in this work is going forward satisfactorily he said.

This meeting is an annual affair to which only members and their immediate families are invited and golf, cocktails, and banquet are the order of procedure. Chairman Henry A. Dierks turned the gavel of office over to D. C. Helms for 1951-52. Mr. Helms' acceptance speech was an extremely interesting talk on some of the accomplishments of the Institute. J. M. Reid was elected Vice-Chairman and F. S. Sanders was elected Secretary-Treasurer. Mr. Walter B. Petzold and the other members of the arrangements committee were complimented on the splendid arrangements which were made to handle the 230 in attendance.

Open-Pit Div. Of Arizona Section Holds Meeting

The Open-Pit Div. of the Arizona Section recently held a successful meeting at Inspiration. Approximately 73 people went on a trip through the mine, crushing plant, and truck repair shop of the Inspiration Consolidated Copper Co. A luncheon at the Cobre Valley Country Club was followed by a technical session.

There were papers on truck haulage at various mines, advances in truck haulage, and drilling practice at Phelps Dodge, Ajo. An interesting discussion was held on the principle concerning torque converters applied to open-pit truck haulage.

Journal Articles To Be Microfilmed

A contract has been renewed with University Microfilms, Ann Arbor, Mich. for microfilming complete annual volumes of the three AIME monthly journals, including the Transactions sections. Microfilms of the 1950 volumes are now available from University Microfilms to those who receive the journals. The AIME receives a royalty of 10 pct of the sales price. The microfilm record is valuable to libraries and others who wish to have a complete record stored in a minimum of space.

Transactions Volumes Distributed

All three AIME Transactions volumes for 1950 were published earlier in the year and are now available. They cover all technical papers, notes, and discussions published in the Transactions section of the three journals in 1950, and nothing else except an index and title page. Vol. 187 contains the papers of the Mining Branch, Vol. 188 of the Metals Branch, and Vol. 189 of the Petroleum Branch. Copies have been mailed to all who ordered them. If not received, the Secretary's office should be notified. The price of each volume is $7, less a 30 pct discount to AIME members. If ordered when dues are paid, Vols. 184 et seq. are available to members at a special discount of 50 pct, or $3.50. "*Statistics of Oil and Gas Development and Production*" covering 1949 is also available; the price is $6 with 50 pct discount to AIME members no matter when ordered. This volume includes the data that were published during the year 1950 in the JOURNAL OF PETROLEUM TECHNOLOGY.

The second edition of "*Basic Open Hearth Steelmaking*" was published early in July (940 p.). It is completely revised and enlarged. It was edited by W. O. Philbrook and M. B. Bever, in collaboration with H. B. Emerick and B. M. Larsen, and was sponsored by the Seeley W. Mudd Memorial Fund as one of the Seeley W. Mudd Series. The price is $8 less the usual 30 pct to AIME members.

ORGANIZATION

AND

STRUCTURE

OF

AIME

AIME is governed by a Board of Directors through the administration of a Secretary, who is the chief executive officer of the Institute. He has a paid staff to assist him. Members of the Institute may enroll themselves with one or more of ten professional Divisions, and some 45 geographical units called Local Sections (Fig. 1). The former attachment is desirable because of specialized technical interests and the latter because of geographical distribution. In a few geographic areas special interest groups also hold local meetings, e.g. the Petroleum Branch chapter in Southern California, the Institute of Metals Div. Regional Conference in New England, eight Open Hearth Committee Local Sections of the Iron and Steel Div., and the Northwest and Rocky Mountain Industrial Minerals Div. regional meetings. Local Sections sometimes have Subsections and usually have Student Chapters under their jurisdiction. Each member of the Institute, if conveniently situated, may increase his participation in the activities of AIME by attending Local Section meetings and serving on Local Section committees. Delegates from each Local Section serve on a Council of Section Delegates which acts as an advisory group to the Board of Directors on the conduct of Institute affairs and has a major voice in naming the Nominating Committee to select AIME officers.

Eight of the ten professional Divisions are grouped into three Branches: Mining, Metals, and Petroleum (see Fig. 1). The Branch Council is the unifying link between the Divisions within each Branch. The Councils function through paid Secretaries and through the Branch Journals.

Board of Directors

The Board of Directors, which sets the policy of the Institute, is made up of a total of 37 Directors including all officers except the secretary, and the Chairmen of the ten professional Divisions, ex officio. The Board has an open meeting about every three months to transact business, the minutes of which are sent to all Local Section Chairmen. In intervening months routine business is taken care of by meetings of the Executive and Finance Committees whose minutes are sent to all Directors. The Board receives suggestions from the various groups of the Institute by verbal presentation at the meetings or by written statements.

Institute Standing Committees

On the national level some service committees coordinate the work being done by the counterpart Divisional committees. The *Nominating Committee* selects candidates for the national officers and directorate. The *Membership Committee* plans and directs the work of getting new members. The *Program Coordinating Committee* meets before the Annual Meeting and, acting on information from the Divisional *Program Committees*, coordinates the programs of the Divisions. The *Institute Publications Committee* supervises the Transactions publication budget and gives final approval on the acceptance and publication of technical papers.

The *Executive and Finance Committees* of the Board of Directors meet monthly or as often as necessary to transact Institute business. They prepare the budget and are responsible for Institute finances. The *Admissions Committee* passes on applications for membership and changes of status and makes recommendations for appropriate action to the Board on each candidate.

Institute Finances

The income of the Institute is derived from the dues and initiation fees paid by its members, advertising revenue, sale of magazines and books, and interest on Institute fund investment. In some instances exhibit space at conventions is sold. The main expenses of the Institute are for its publications and the salaries of the staff responsible for its administration; other expense is incurred for appropriations, assessments, and rent.

Secretary

The Secretary is responsible to the Board for the conduct of Institute business and the operation of the headquarters offices in New York, Dallas, and Salt Lake City. The various departments of New York headquarters consist of the national Secretary's office and those of the Metals and the Eastern Mining Branch Secretaries, respectively, the publications, accounting, order, purchasing, convention, membership directory, mailing, and filing departments. MINING ENGINEERING and the JOURNAL OF METALS are published in New York. The Dallas office, under the direction of the Petroleum Branch Secretary, publishes the JOURNAL OF PETROLEUM TECHNOLOGY and conducts Petroleum Branch affairs.

ORGANIZATION OF AIME

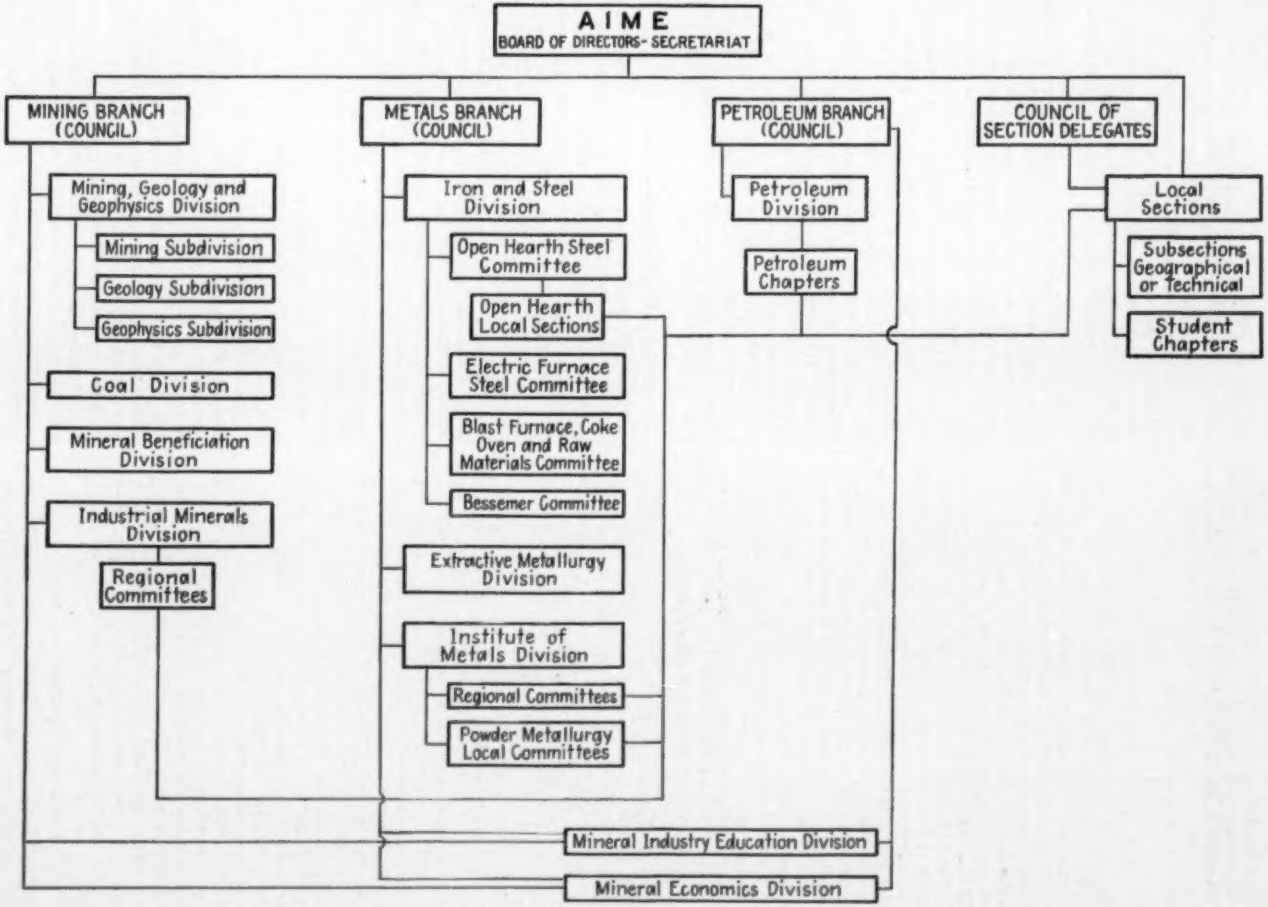


Fig. 1.

The office of the Western Secretary of the Mining Branch has been established in the Newhouse Bldg., Salt Lake City, Utah. It is the duty of this Secretary to maintain contact with the Local Sections, Student Chapters, and members in the West; to help the Divisions with meeting arrangements and committee appointments; to assist in membership work; and to keep the editors of the Institute journals abreast of news in the West.

Local Sections

The Local Sections, distributed all over the United States and to a limited extent in other countries, are the backbone of the Institute because they provide facilities for the frequent congregation of groups of members for technical and social affairs. It is the duty of Section officers to arrange technical meetings, inspection trips, and other activities, to fulfill the bylaws of the Section, to maintain contact with the headquarters office, and to do everything possible at the local level to promote the welfare of the Institute and to work for the professional advancement of the members. Headquarters will supply Local Sections with as much aid as possible. Each year the Local Sections are entitled to receive an appropriation of money for the conduct of affairs and also receive 10 pct of the initiation fee paid by each new member in their territory. The Local Section should report its meetings for publication in the journals and send notices of its coming meetings to headquarters sufficiently in advance for publication (about 2 months before the meeting). The Local Section must appoint a delegate, with an alternate, to attend the Annual Meeting of the Council of Section Delegates. His travel expenses, within certain limitations, are paid out of the Institute treasury. The Delegates may carry petitions or suggestions from the Section members for consideration by the Council and by the Board. The Delegates must also, upon return from the meeting, report on it to the membership of the Section.

Many active Local Sections also perform other services for the members, such as sending speakers to the Student Chapters in the area, holding a student prize paper contest, a "student night" meeting, and allowing students reduced prices at dinner meetings. Occasionally a Division or the entire Institute is invited to hold a meeting for which the Section acts as host. The Local Section should take an active part in trying to increase Institute membership within the geographic area of the Section. Local Sections whose membership is scattered sometimes have subsections which hold meetings individually or jointly with the entire Section. A Section with a large group of members interested in more than one of the Divisions or Branches of the Institute may set up technical subsections which hold meetings individually on subjects of more specialized interest. The Arizona Section is an example. The Southern California and Minnesota Sections have technical subsections which are affiliated with the counterpart national Divisions.

Branch and Divisional Structure

The Institute is divided into three major Branches, Mining, Metals, and Petroleum. The Mining Branch comprises four Divisions—the Mining, Geology, and Geophysics Div. (which has subdivisions on each of these three topics), the Minerals Beneficiation, Industrial Minerals, and Coal Divisions. The Institute of Metals, Iron and Steel, and Extractive Metallurgy Divisions make up the Metals Branch. The Institute of Metals, the oldest Division of the Institute, is concerned with the physical metallurgy of ferrous and nonferrous metals. The Iron and Steel Div. deals with the production of iron and steel and the Extractive Metallurgy Div. with nonferrous production metallurgy. The Petroleum Div. is the only Division in the Petroleum Branch. It deals with the exploration for and production of oil. The Mineral Industry Education and the Mineral Economics Divisions are represented in all three Branches and are therefore Institute-wide Divisions (see Fig. 1).

Each of the three Branches publishes a journal. They have paid secretaries and an editor who help with meeting arrangements, the handling of technical papers, keep the Divisions informed, and see that Branch interests are represented in all matters at headquarters. The Divisions function through officers and committees. Coordination between the Divisions within the Branches and between the Branches themselves is provided by the Branch Councils and the Secretaries.

The Divisions are represented on the Board of Directors both by their Chairmen *ex officio* and by elected Directors that are Division members and thus have a voice in the operation of the Institute. They receive an appropriation in the annual budget.

The primary function of the Divisions is to sponsor meetings on technical subjects and to publish papers providing a record of technical progress in their particular field.

Mining Branch Divisions

Mining, Geology, and Geophysics Div. was formed in late 1949 to unite the old Mining Methods, Mining Geology, and Geophysics Committees into one Division. The chief outcome of this union is a coordinated program effort which has provided numerous joint technical sessions for the discussion of subjects of mutual interest. Each of the three Subdivisions has its own officers, program, publication, and other committees. Division officers are elected from the officers of the Subdivisions.

The *Industrial Minerals Div.* is the oldest Division in the Mining Branch. It was formed for the advancement and dissemination of knowledge on the geology, mining, preparation, use, and economics of nonmetallic minerals with the exception of coal and petroleum.

The *Coal Div.* is interested in all phases of the coal industry including reserves, mining, preparation, utilization, synthetic fuels, and markets.

The *Minerals Beneficiation Div.* is a functional Division dealing with concentration and preparation processes of all minerals. Generally speaking it covers those processes which take place at the mine, and stops before treatment of ores at smelters. It does, however, discuss unit processes of interest to many members of the Extractive Metallurgy Div.

There are subjects of mutual interest between all Divisions within the Mining Branch. This gives unity to the Branch as many joint meeting sessions are possible and papers of all Divisions are published in a common journal, MINING ENGINEERING.

Divisional Committees

Each Division has several technical and what might be termed "service" committees. All of the

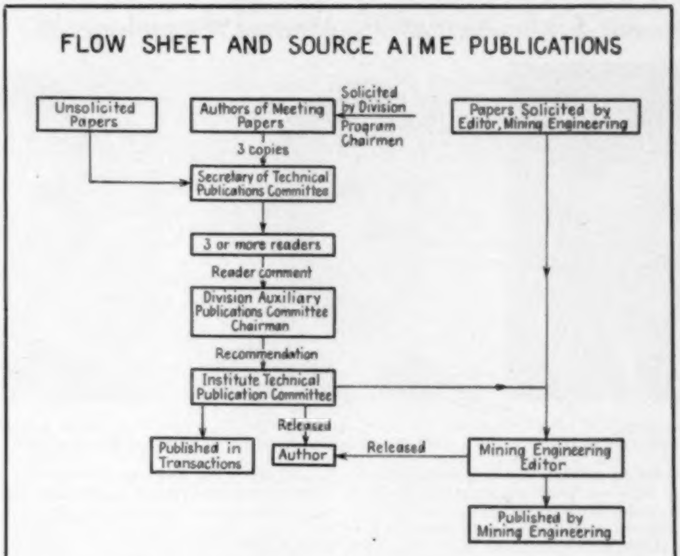


Fig. 2.

technical committees help provide papers on various specific subjects.

There are usually four service committees: The Nominating, the Program, the Auxiliary Publications, and the Membership Committees. The Nominating Committee names candidates for the various offices of the Division as specified in the bylaws.

The Program Committee solicits papers and organizes programs of the respective Divisions for the Annual Meeting and other meetings which the Division is sponsoring or in which it is participating.

The Auxiliary Publications Committee sends each paper which is submitted for consideration for *Transactions* to readers who make recommendations regarding its disposition. It reviews these recommendations and reports to the Institute Technical Publications Committee. Briefly, the Program Committee solicits papers which, when submitted, are passed on by the Auxiliary Publications Committee.

The Membership Committee cooperates with the national Chairman of the Membership Committee and the Institute staff in getting new members.

Mining Branch Council

The Mining Branch Council is made up of the Division Chairman and immediate past-Chairman of each of the four Divisions of the Mining Branch. In addition, the Mineral Industry Education and Mineral Economics Divisions each has a representative on the Council. The Council can advise the Board of Directors on matters affecting the Mining Branch such as allocation of monetary and *Transactions* page budget to the Branch and among the Divisions of the Branch. It advises on publication policy for MINING ENGINEERING magazine. Problems arising between Divisions of the Branch may be discussed and worked out at Council meetings. In all matters where an expression of opinion by the members of AIME in the Mining Branch is desired, the Mining Branch Council can be the spokesman.

MINING ENGINEERING Magazine

MINING ENGINEERING is the official publication of the Mining Branch of AIME. It contains news, operating, economics, and education articles, reviews, AIME and industry news, and advertising. These articles are selected or written by the editorial staff. Many of them are Annual, Regional, Divisional, or Local Section meeting papers. Some papers which are not acceptable for *Transactions* but are of current interest, are referred by the publications committees to the editor for publication in the magazine.

Mining Transactions papers are also published in MINING ENGINEERING magazine. These form the official AIME record of mining technology. When the *Transactions* are printed for the magazine, enough copies are overrun for binding in the annual volume. This is sold to the members for a nominal charge. *Transactions* are those papers judged by selected critical readers to be of permanent interest for the AIME record of technology. Anyone may submit a paper for *Transactions*. Many of those published have been presented at meetings. Some meeting papers, however, are of only current or local interest and are not suitable for *Transactions*. Papers to be considered for *Transactions* must be sent in triplicate to the Secretary of the Institute Technical Publications Committee (E. J. Kennedy, Jr.). These papers are passed on by a reader routine which is diagrammed in Fig. 2.

Any paper may be considered for *Transactions* whether it is presented at Local Section, Annual, Regional, or Divisional meetings. However, it is not necessary that a paper be presented at a meeting for it to be considered. Many are submitted by engineers or geologists, whether AIME members or not, direct to the Secretary of the Technical Publications Committee.

Program Set for Nonmetallics Meeting Morgantown, W. Va.

P. H. PRICE
General Committee Chairman

J. C. LUDLUM
Program Committee Chairman

H. W. AHRENHOLZ, JR.
General Arrangements Committee Chairman

THE final program for the Fall Meeting of the Industrial Minerals Division AIME has crystallized. The meeting is to be held at West Virginia University, Morgantown, W. Va., Sept. 13 to 15. Co-sponsors of the meeting are the Central Appalachian and the Ohio Valley Sections of AIME. Registration and technical sessions will be in the Mineral Industries Building on the campus. Registration fee for members is $5, nonmembers $6, Student Associates $1, other students $1.50, and ladies $1.

The meeting will begin with registration and technical sessions on Thursday morning followed by field trips in the afternoon and a buffet dinner and social hour at the Mont Chateau Hotel on Cheat Lake in the evening. On Friday there will be a full day of technical sessions, a luncheon at the University cafeteria, and a cocktail party and informal banquet at the Hotel Morgan. At the banquet, Division Chairman A. B. Cummins will preside, Charles E. Lawall will be toastmaster, and Harold Thompson, vice president of Union Carbide and Carbon will be the speaker. Saturday morning will be devoted to field trips.

The technical program and field trips are as follows:

Technical Sessions

Thursday Morning

Co-chairmen: Paul H. Price, state geologist of West Virginia and A. B. Cummins, Chairman, Industrial Minerals Div.

Geologic Setting of Mineral Resources of West Virginia. By John C. Ludlum, associate professor of geology, West Virginia University.

Limestone Production in West Virginia. By Robert C. Brand, Brand Engineering Co.

Industrial Quartzite in Virginia. By B. N. Cooper, head, dept. of geology, Virginia Polytechnic Institute.

Sulphur from Coal. By K. L. Temple, assistant research specialist, Engineering Experiment Station, West Virginia University.

Friday Morning

Co-chairmen: G. R. Spindler, director, School of Mines, West Virginia University and J. S. Machin, head, industrial minerals div., Illinois Geological Survey.

Lithium in the Chemical Industry. By P. E. Landolt, executive vice president, Lithium Corp. of America.

Artificial Brine Production of Salt at Natrium, W. Va. By J. J. Ehlers, assistant plant superintendent, Southern Alkali Corp.

Salt Production from Natural Brines. By R. E. Greter, field superintendent, Westvaco Chemical Corp.

Clays and Other Raw Materials for the Ceramic Industry. By Paul R. Jones, associate professor of ceramic engineering, West Virginia University.

Friday Afternoon

Industrial Water Supply in Ohio and West Virginia. By Richard J. Anderson, assistant supervisor, Battelle Memorial Institute.

Recent Developments in the Sulphur Situation. By J. C. Carrington, assistant to the president, Freeport Sulphur Co.

Refractories Problems in Direct Coal Gasification with Oxygen. By J. B. Cordiner, Jr., chemical engineer, U. S. Bureau of Mines.

Coal as a Chemical Raw Material. By Walter A. Koehler, head, chemical engineering dept., West Virginia University.

Field Trips

Thursday Afternoon

Morgantown Ordnance Works. Leader, T. Arkle, Jr., West Virginia Geological Survey. This plant is designed to produce synthesis gas from coke for the manufacture of ammonia, in particular, and also methanal, hexamine, and ethylene urea. Names of those wishing to take this trip must be in by Aug. 15 for clearance.

Weirton Mine Coal Preparation Plant. Leader, H. Wm. Ahrenholz, Jr., School of Mines, West Virginia University. A Baum jig is in operation at this plant. After cleaning, the coal is transported 2 miles underground on a single continuous belt to the Monongahela River for shipment.

Coal Gasification Experiment Station, U. S. Bureau of of Mines. Leader, A. E. Sands, U.S.B.M. This experiment station has facilities for investigating the production of synthesis gas directly from coal.

United Sanitary Corp., Mannington, W. Va. Leader, P. R. Jones, dept. of chemical engineering, West Virginia University. Manufacture of china sanitary ware by the slip-casting method, including preparation of raw materials, casting, drying, glazing, and firing.

Saturday Morning

Greer Limestone Mine. Leader, Jesse L. Dally, geology dept., West Virginia University. Underground mining of limestone by room-and-pillar method, for use as road metal, rock dust, paving material, and agricultural purposes.

Arkwright Coal Mine. Leader, T. Arkle, Jr., West Virginia Geological Survey. Underground mining of coal in the Pittsburgh seam.

Trips to the Weirton preparation plant and the U. S. Bureau of Mines gasification plant will be repeated on Saturday.

A Tribute to A. F. Taggart at His Retirement from Teaching

Arthur Fay Taggart, professor of mineral engineering at the School of Mines, Columbia University, retired from teaching on July 1. This ends one of the greatest teaching careers in the history of ore dressing.

Taggart's approach to teaching stems from the conviction that an engineer is paid primarily for his ability to think and for his ability to communicate his thoughts by the written and spoken word. Thus, all of his course offerings at the university could have been titled: *Problem Attack, Report Writing, and Speech.* He would often express his attitude by the remark, "I do not care whether you learn anything about ore dressing so long as you learn how to attack a problem, solve it, and tell others what you have done."

Taggart's attack on problems is best illustrated by his instructions to students which were invariably put in the form of questions. One triology of such questions was: "What is it and what does it do? How does it do it? How well does it do it?" The "it" was usually some machine or process. Another set of questions was: "Where are we? Where do we want to go? How do we get there?" By application of the divide and conquer technique he taught his students that no problem was too big no matter how imposing. The students were instructed to analyze the problem into component parts; to solve the problems associated therewith; then, by conjoining the solutions of the parts, to synthesize the solution of the whole. The key to Taggart's approach was questions; big questions, little questions, millions of questions, questions and then more questions—always *why?*—innocently sounding questions, questions where there seemed to be no questions, questions which transformed the commonplace into an exciting unknown. In this phase of his teaching Taggart himself became an animated question mark. No student subjected to this treatment could help to realize how little is known about ore dressing, how many exciting problems there are to solve, and how they may be solved by systematic attack.

It seems unbelievable that this inquiring attitude could be further intensified—but it was, with respect to students engaged in research. There the problem was a big formidable *question.* By mating with the student's intellect, it was made to yield a first generation of less forbidding questions, these in turn gave rise to a second generation of still less imposing questions and so on until a generation of questions more or less easily answered was produced. Answers were produced, the process was reversed, until these resulted by synthesis an answer to the initial question.

The importance that Taggart assigned to report writing derived from the realization that in these days of large companies with far-flung operations, management first becomes acquainted with the young engineer via their reports and from the realization that reports provide an opportunity for personalized instruction through criticism. Reports were read critically—every word, every comma. The comments often exceeded in length the student's report. The student was instructed that the report was to be a written record of *what you did, what you saw, and what you think about it.* Seventy-five per cent of the report concerned itself with what the student thought of what he had observed. This was to be summarized by conclusions drawn by logical argument from the observations. The students soon learned to differentiate between opinions and conclusions from facts; between conjectures and theories.

The criticisms of the reports were penetrating and devastating. To the student writing in chatty and gossipy style about everything and nothing in particular his final comment was: "This is the kind of stuff I expect from the ladies. I am not in the mood for the fair sex this morning." To the student fawning on the wonders of engineering but saying nothing otherwise: "This is of the nature of drool." To the student using gobledegook: "This is pure drivel." One student thinking to soften the inevitable criticisms inserted a note to the effect that he had a cold at the time the report was written. Taggart, reading with his usual care, corrected all misspelled words and innumerable typographic errors finally queried, "Does your typewriter also have a cold?" To the student substituting for argument facility with language his final comment was: "This has the form but not the substance of a good report."

As with his questions, Taggart's criticisms were often couched in irritating terms. In fact this was one of the secrets of the inspirational teaching he practiced. You might not like him but you could not be unaware of him. It was done purposely to break through the crust of lethargy; to make one mad enough to do something about it. Taggart forced one to take some position on every disputable technical situation. The fence straddler was flayed unmercifully. He often took a position regardless of his real thoughts so as to provide argument and discussion for he knew that clarification and new knowledge often ensued. His attitude both at the university and in the field is most aptly expressed by a remark he once made: "Truth is not found in the middle of the road."

To the advanced student Taggart taught the value and power of generalization. In this field he was unexcelled. His intellectual daring coupled with a most fertile imagination produced a never-ending stream of speculation. Then the sound engineer interceded to check and recheck the speculations against the facts.

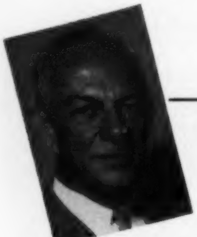
Taggart's greatest contribution to the literature of ore dressing are his generalizations. The handbooks of ore dressing and mineral dressing are not mere compendia of practice to knowledge—they are repositories of the ordered knowledge of the field tied together with broad generalizations which at once condense and unify this knowledge. His contributions to the theory of flotation are similar in character.

This is not intended as an appreciation of Taggart the engineer, that chapter has yet to be completely written. Those of us who have been fortunate enough to know the man intimately, know as a conclusion from the facts of his life that he will continue to be active professionally. Nor is it really true that his teaching career is ended for the seeds he has sown via the men he has educated have sprouted and will grow and will in turn re-seed Taggart's ideas and methods in other men. There is no end.—**M. D. Hassialis.**

San Juan Subsection Holds June Meeting at Ouray, Colo.

Field trips to the mine and mill of Idarado Mining Co. and to the historic Camp Bird mine of King Lease, Inc., high lighted the June 22 to 23 meeting of the San Juan Subsection of AIME held at Ouray, Colo. Thirty went on the Idarado trip, which was on Friday, and were the guests of the company for lunch at the boarding house. On Saturday, following the visit to the Camp Bird mine and a luncheon, 111 convened for a technical session. Interesting and informative papers were delivered by J. Fred Johnson, who read a paper by John G. Hall, G. A. Franz, Jr., C. A. Rasor, Marvin Kay, and Franklin Bell. The election of officers followed. Robert E. Tally was elected Chairman, J. W. George, Vice-Chairman and R. D. Van Zante, Secretary-Treasurer.

Following a sociable cocktail hour, dinner was served to members and guests. R. G. Sullivan, outgoing Chairman of the San Juan Subsection acted as toastmaster and W. McG. Peirce, President of the Institute, gave the principal address on AIME affairs.



THE DRIFT OF THINGS

by Edward H. Robie

OWING to the fact that the usual Fall Meeting, or Mid-Year Meeting, or Regional Meeting, as it was variously called, was not held in 1950, many AIME members are wondering if any definite policy has been adopted as to its continuance. Although scheduling of the Fall Meeting is done on a year-to-year basis, there is no ground for the idea that such meetings will not be held at least fairly regularly in the future. Last year a combination of circumstances prevented holding such a meeting. The American Mining Congress held an important convention and exhibition at Salt Lake City late in August. The AIME was to hold its Annual Meeting in St. Louis in February 1951. To hold another national meeting in the Midwest or Far West in the interval between seemed, especially with a war going on, to be putting somewhat of a strain on the membership, both in preparing for and attending such a meeting.

This year the Fall Meeting is being resumed, of course, with the Mexico City meeting, Oct. 29 to Nov. 3. Next year, the Fall Meeting will be held in Chicago, sometime in the week beginning Sept. 8. This is the time of the Centennial of Engineering celebration, which the American Society of Civil Engineers is sponsoring in connection with its 100th anniversary. Many engineering societies will hold fall meetings in Chicago at that time, so that papers of general interest, or joint interest with other groups, will be especially appropriate. Several AIME Divisions are likely to participate in the program, though few have made any definite plans. No plans have yet been made for the Fall Meeting of 1953, so that invitations will be considered from any Local Section or city that wishes to sponsor a meeting at that time. A suggestion has been made that it be held in Montreal, with a field trip to some of the Canadian mining properties.

As to Annual Meetings, the present plan is to alternate them between New York and another city: New York 1948, San Francisco 1949, New York 1950, St. Louis 1951, New York 1952, Los Angeles, 1953, New York 1954, possibly Houston or some other petroleum center 1955, New York 1956, possibly Chicago 1957.

Chance to Clean House

Out in the country where we live the serenity recently has been punctured more often than formerly by the bells of the junkman's truck. It used to be that payment for scrap metal was little or nothing. The junkman charged as much for taking away the stuff that neither of us wanted as he was willing to give for the stuff that he could use. Anything of heavy metal now seems to be in demand, and the junkman's face lit up no end when we found an old cast iron stove for him. This led us to look into the situation a bit, and we find that steel producers are really threatened with a scrap shortage more serious than that which occurred about 10 years ago. Supplies of heavy industrial iron and steel scrap are dangerously low. Scrap inventories have dropped from two months' supply to stock sufficient only for a few days or weeks, according to the American Iron and Steel Institute.

Of the 1½ billion tons of steel now in use in the United States, millions of tons normally are discarded each year and eventually return to the mills as scrap. During World War II between 110 and 120 million tons were diverted overseas, and scarcely any came back to this country. Scrap has not been exported recently in any quantity, but the country's immense steel production, at the rate of 104 million tons a year, exceeding by 10 pct the World War peak, has absorbed an enormous amount of scrap. Producers would like to have about 60 pct scrap and 40 pct virgin metal to make steel to the best advantage; currently the proportions substantially are reversed.

The scrap cycle, steel from mill to product and back to mill, must be restored quickly to maintain current production, to say nothing of building up depleted inventories to carry mills through the winter months when collections fall off. Government, industry, and agriculture can aid in war preparedness and provide a public service by conducting an emergency inspection of their properties and sending obsolete machinery and equipment to the nearest scrap dealer. There will be no better time for housecleaning than now, in spite of the shortage of labor in many plants. All available heavy scrap is urgently needed.

Finding Summer Jobs

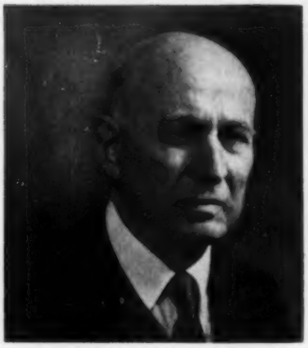
Though organized only three years ago, the Institute's Minerals Beneficiation Div. is one of its most active groups. Among its committees is the Education Committee, which one might perhaps be pardoned for thinking would have more or less prosaic activities. But under the chairmanship of Rush Spedden, at M.I.T., it is really doing a job that other committees might emulate. It has tackled the problem of summer jobs for students.

Its plan is designed: (1) To help students find suitable summer jobs so that they can get some valuable working experience while earning money to help meet the rapidly increasing cost of an education; and (2) To give the mining and metallurgical companies of this country a chance to have a wider choice of technical employes. Through a few months of summer work a company easily may appraise the capabilities of a man they may wish to employ later. The student himself may discover an interesting problem for a thesis or special project for his senior year.

Professor Spedden sent questionnaires to some 70 companies operating minerals beneficiation plants. He asked them how many students could be employed, the type of work available and the pay scale, living accommodations, special qualifications desired, preferences and restrictions, and the dead line for the receipt of applications. Upon receipt of the returned questionnaire, it was copied and sent to the Faculty Sponsors of interested Student Chapters. The students were invited to apply for the jobs on another prepared form, which gave the employer the information he would be likely to wish to know about the applicant.

More will be known about the success of the scheme by the end of the summer. An appreciable number of the employers approached replied with requests for several men, and presumably many students were thus placed in work in which they were especially interested.

Personals



WALTER H. ALDRIDGE

FRED M. NELSON

B. J. DISANTO

Walter H. Aldridge has been elected chairman of the board, Texas Gulf Sulphur Co. and **Fred M. Nelson** has been elected president of the firm. Mr. Aldridge has been president since the company began its operations 32 years ago. Mr. Nelson was formerly in charge of many of the company's field operations since he joined the firm in 1927. Last year he was elected executive vice-president of a Mexican subsidiary of the company.

Tacettin Ataman has become general manager of E.K.I., Zonguldak, Turkey.

Jose A. Bacigalupo is chief of industrial dept., Solid Fuels Administration, Florida, Buenos Aires.

Lionel E. Booth is now associated with Hardinge Co., Inc. as representative in Salt Lake City.

Weston Bourret, Pasadena, Calif., has been appointed chief of the Minor and Rare Metals Branch of the DMA Supply Div.

Stoddard S. Burg has accepted a position with the Ingersoll-Rand Co., Phillipsburg, N. J. Mr. Burg was recently awarded the Old Timers' Award at Pennsylvania State College, State College, Pa.

Philip A. Beeson has been promoted to metallurgist, Bradley Mining Co., Stibnite, Idaho.

F. W. Bloecher, Jr. has joined the American Cyanamid Co., atomic energy div., Watertown, Mass.

Blandford C. Burgess is now located with the ECA-MF, c/o American Embassy, Paris. Mr. Burgess has been traveling quite extensively through London, Tripoli, Johannesburg, and Southern Rhodesia in his capacity with ECA.

Peter A. Bosher may be contacted at the National Bank of Australasia Ltd., London, E.C.2. He will be in England for approximately 2 years.

W. E. Bearce is now with the Hanna Coal Co., St. Clairsville, Ohio.

John R. Bogert is now employed as a geologist with the Kennecott Copper Corp., Lima, Peru.

A. A. Bradd, formerly an engineer with the Arcos Corp., Philadelphia, has joined the Midvale Co., Philadelphia, as roll engineer.

John L. Brixius has joined the Miami Copper Corp., Miami, Ariz.

W. Keith Buck is now a mining engineer, Mineral Resources Div., Bureau of Mines, Ottawa.

Ian Campbell, California Institute of Technology, was recently in Washington, D. C.

John J. Collins has resigned from the USGS to take a position with the mining dept., American Smelting & Refining Co. He will be located in London as special representative in Europe and Africa.

W. R. Chedsey, professor at the University of Illinois has gone to Tokyo on a government mission. He is in a group of engineering educators planning to visit colleges and schools of Japan examining educational methods.

M. W. Cox has returned from France and can be contacted at Wallace, Idaho.

B. E. Charles is now employed by Nevada Scheelite, Inc., Rawhide, Nev.

John E. Douglas, sales engineer for Joy Mfg. Co., has been transferred to El Paso.

B. J. DiSanto, former assistant plant manager at the Perth Amboy plant of American Smelting & Refining Co., has been transferred to Salt Lake City as chief engineer of the primary lead and copper smelters and refineries.

Carl Dietz, president of Lamson Corp., Syracuse, N. Y., was awarded the honorary degree of Doctor of Engineering by Stevens Institute of Technology, Hoboken, N. J.

Lewis W. Douglas, former American Ambassador to the Court of St. James has been elected a director of International Nickel Co. of Canada, Ltd.

Richard D. Ellett has resigned from the Newmont Mining Corp. to accept a position as geologist with National Lead Co. in Mexico.

Roland Erickson has joined the engineering dept. of the Reserve Mining Co., Babbitt, Minn.

B. F. Eads has joined the Truax-Traer Coal Co., Kayford, W. Va., as engineer in training.

Herbert D. Fine has accepted the position of chief engineer for Frontino Gold Mines, Ltd., Colombia.

W. H. Fitzsimmons is now employed in the research laboratories of the American Cyanamid Co., Stamford, Conn. He was formerly with South American Development Co., Guayaquil, Ecuador, as assistant general superintendent.

Thomas James Greene, Jr. has become an engineering trainee for the Texas Co., Rosenberg, Texas.

L. O. Goodman, Jr. has resigned from the Cerro de Pasco Corp., Casapalca, Peru.

Derric A. R. Hanvey has joined the Filani Tin Mining Co., Ltd., British West Africa.

L. H. Hinckley is now employed by the Philippine Iron Mines at Larap, P. I. He had been associated with Marsman & Co.

William S. Hutchinson, Jr. has resigned from the AEC, Grand Junction, Colo. to accept a position as general superintendent, Eureka, Ltd., Eureka, Nev.

Donald W. Hammerquist has accepted a position as junior geologist with National Lead Co., St. Louis smelting & refining div., Fredericktown, Mo.

James B. Hustad has left the employ of the Oliver Iron Mining Co., Duluth, and is now developing a small magnetite-hematite deposit in Puerto Rico.

John C. Haddock is now president, Morris Run Coal Mining Co., Wilkes Barre, Pa.

Victor D. Jenson has accepted a position as assistant quarry engineer, U. S. Gypsum Co., Midland, Calif.

Daniel B. Johnson, formerly of Long Beach, Calif., is now general superintendent, Fresnillo Co., Naica unit, Chihuahua, Mexico.

James H. Jensen, previously plant engineer for the Pacific Carbide & Alloys Co., Portland, Ore., has recently taken a position on the engineering staff of the Great Lakes Carbon Co., Chicago.

Henry P. Kirchner, formerly with the Carborundum Co., Vancouver, Wash. has returned to Pennsylvania State College to carry out advanced work in ceramics.

Arthur A. Krieger has joined the Standard Mining Corp., Grand Junction, Colo.

Henry Krumb, mining engineer of New York, was the recipient of the honorary degree of Doctor of Science awarded by Columbia University.

WALTER C. LAWSON

Walter C. Lawson, manager of the New Cornelia branch of Phelps Dodge Corp., has been named assistant to the vice-president and general manager at Douglas.

I. M. LeBaron has been appointed director of research laboratories for International Minerals & Chemical Corp., Chicago.

Stuart H. Levinson has been elected vice-president in charge of zinc and coal operations of the American Smelting & Refining Co.

Charles H. Lambur, U. S. Collieries, Inc., has left for Europe where he will spend several months working on coal export and various technical matters of foreign mine management and operations as compared to American methods.

George P. Lutjen, formerly associate editor of the Engineering & Mining Journal, has joined the AEC, New York, as a mining engineer.

L. H. Lange, vice-president and manager of the metallurgical div., Galigher Co., Salt Lake City, returned to the United States after 5 months abroad. He visited Johannesburg, Southwest Africa, northern and southern Rhodesia, and London.

Arnold H. Miller, consulting engineer, New York, has been appointed

by the Chilean government to do work in connection with plans for a new electrolytic copper refinery.

W. W. Mein, Jr., has been appointed president of the Calaveras Cement Co., San Francisco. He was formerly vice-president of the firm.

Richard D. Moody has been promoted to district manager, Allis-Chalmers Mfg. Co., Los Angeles.

Gordon B. Mackenzie has resigned from the Sierra Leone Development Co., Ltd., Sierra Leone, West Africa.

Charles A. Mitke is at present examining mining properties in Brazil.

Harold Meese, formerly professor in the metallurgical engineering dept., Michigan College of Mining & Technology, has been recalled to active duty with the U. S. Navy.

Jack S. Mott, chief engineer for Induflux Testing Service, Los Angeles, is now district engineer at the Oklahoma City office.

Donald R. MacLaren is now with the Alaskan & Foreign Geology Branch, USGS, Washington, D. C.

J. M. McCoy has joined Robinson & Robinson, mining engineers, Charleston, W. Va. He was previously with the Truax-Traer Coal Co., Kayford, W. Va.

D. Gilbert Monroe, previously with Boeing Aircraft Co., Seattle, has joined the Gilmer Lode Mining Co., College, Alaska.

CHARLES H. MOORE

Charles H. Moore has been appointed technical director for the Feed Materials production center to be constructed near Cincinnati. It will be operated by the National Lead Co. for the AEC.

Douglas M. Marshall is now an engineer with the Webb Coal Mining Co., Garrison, W. Va.

Hugh C. Mason has returned from Trujillo, Peru and is now residing at Somerville, Mass.

J. C. G. Moore has joined the Photographic Survey Corp., Toronto, Ont.

JAMES MAIR

James Mair, vice-president of the Goslin-Birmingham Mfg. Co., Inc. was awarded the professional degree of chemical engineer by the University of Alabama.

Clifford R. Nichols is now general manager, El Dorado Limestone Co., Shingle, Calif.

Fred F. Netzeband has taken a position as commodity specialist in the Economics Div., U. S. Bureau of Mines, Amarillo.

James Peterkin Norrie was made general manager, Roan Antelope Copper Mines Ltd., Northern Rhodesia.

Phillip C. Nicolle recently accepted a position in the engineering dept. of the Canadian Mining & Smelting Co., Kimberley, B. C.

C. A. O'Connell is on a tour of mines in Canada and the United States. He recently returned from Northern Rhodesia after an absence of 12½ years.

Harold B. Overstreet was promoted to stope foreman, U. S. Smelting, Refining, & Mining Co., Bingham Canyon, Utah.

J. B. Pullen has been made manager of the New Cornelia div., Phelps Dodge Corp., Ajo and **Carl E. Mills** was appointed manager of the Copper Queen branch.

Charles E. Prior has become resident engineer for the American Smelting & Refining Co., mining dept., New York.

Joseph H. Reid, manager of titanium div., National Lead Co., has been elected a vice-president.

John C. Russell is now associated with the Dorr Co., Stamford, Conn.

Carl W. Sawyer has joined the Idarado Mining Co., Ouray, Colo.

Richard Strong is now a geologist for the Oliver Iron Mining Co., Duluth.

Francis B. Speaker has been appointed chief of the maintenance, repair, and operations branch of the Requirements, div., DMA.

Chester James Stull, Jr., received the Old Timers' Award as the outstanding student in mining engineering at Virginia Tech.

Robert Stillson Sanford is presently on a mining mission in Asia.

P. L. Shields, president of Spring Canyon Coal Co., has been named a member of the Bituminous Coal Producers' Industry Advisory Committee.

Robert H. Stebbins is now a geologist for the Pend Oreille Mines & Metals Co., Metaline Falls, Wash.

Roy Erwin Swift joined the faculty of the dept. of mining and metallurgical engineering of the University of Kentucky, Lexington. He was formerly connected with the Mackay School of Mines, University of Nevada, Reno.

Heath Steele, vice-president of American Metal Co., recently returned from an inspection tour of

the potash properties in New Mexico of the Southwest Potash Corp., a subsidiary of American Metal.

W. G. Stevenson has left the employ of the Chief Consolidated Mining Co. and is now in the geological dept., western mining branch, American Smelting & Refining Co.

Peter O. Sandvik is now employed as an assayer by the Territory of Alaska, Dept. of Mines, Anchorage.

S. C. Sandusky has retired after 25 years service with National Lead Co., St. Louis smelting & refining div. Mr. Sandusky has been engineer, chief engineer, mine superintendent, superintendent, general superintendent, and resident agent, respectively.

Carl F. Schaber has returned to the United States after two years in Yugoslavia where he supervised the erection of the 700-ton blast furnace by Mackenzie Engineering Ltd., London.

R. W. Thomas, general manager, Ray div., Kennecott Copper Corp. has retired after 39 years of service. **A. P. Morris,** assistant general manager will succeed Mr. Thomas, who will remain in an advisory capacity until the end of the year.

Ethem T. Turkdogan has been awarded the degree of doctor of philosophy by the University of Sheffield, England. He has obtained a position on the research staff of the B.I.S.R.A. chemistry dept., London.

Dean F. Thorpe has joined the American Cyanamid Co., mineral dressing laboratory, Stamford, Conn.

James W. Van Evera, Jr., is now a mining engineer with the Jones & Laughlin Steel Corp., blair limestone div., Martinsburg, W. Va.

Burton J. Westman is now located at Portland, Ore.

Thomas Walker, Jr., is now employed as a sales-serviceman with the Hercules Powder Co., Hibbing.

Samuel I. Wright is now employed by the Iron Mines of Venezuela, San Felix, Venezuela.

Clyde Williams, director of Battelle Memorial Institute was recently awarded the degree of doctor of science by Ohio State University.

Leland A. Walker, consulting engineer from Salt Lake City has accepted a position with the AEC, Grand Junction, Colo.

William H. Wilson has joined the USGS, Tucson, Ariz.

John C. Warner, president of Carnegie Institute of Technology, was presented an honorary degree of Doctor of Science by Northeastern University, Boston.

— Coming Events —

Aug. 7, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Aug. 27-Sept. 6, Oak Ridge National Laboratory and Oak Ridge Institute of Nuclear Studies, summer symposium, Oak Ridge.

Sept. 13-14, Oak Ridge Institute of Nuclear Studies, symposium, Oak Ridge, Tenn.

Sept. 13-15, AIME, Industrial Minerals Div., fall meeting, University of West Virginia, Morgantown, W. Va.

Sept. 16-19, American Institute of Chemical Engineers, regional meeting, Sheraton Hotel, Rochester, N. Y.

Sept. 18, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Sept. 19, AIME, Carlsbad Potash Section, Riverside Country Club, Carlsbad, N. Mex.

Sept. 20, AIME, Utah Section, Newhouse Hotel, Salt Lake City.

Sept. 25-28, ASME, fall meeting, Radisson Hotel, Minneapolis.

Oct. 1-4, Assn. of Iron and Steel Engineers, annual convention, Hotel Sherman, Chicago.

Oct. 3-5, AIME, Petroleum Branch, fall meeting, Oklahoma City.

Oct. 8-12, National Safety Congress & Exposition, Palmer House, Stevens, Congress, and Morrison Hotels, Chicago.

Oct. 9-12, Scientific Apparatus Makers Assn., mid-year meeting, Recorder-Controller Section, Seaview Country Club, Absecon, N. J.

Oct. 10-11, Joint Fuels Conference, AIME, Coal Div. and ASME, Fuel Section, Hotel Roanoke, Roanoke, Va.

Oct. 10-12, Electrochemical Society, autumn national convention, Hotel Statler, Detroit.

Oct. 12, AIME, Eastern Section, Open Hearth Committee, Warwick Hotel, Philadelphia.

Oct. 15-17, AIME, Institute of Metals Div., fall meeting, Detroit-Leland Hotel, Detroit.

Oct. 15-19, National Metal Congress & Exposition, Detroit.

Oct. 18-19, Scientific Apparatus Makers Assn., mid-year meeting, industrial instrument section, Seaview Country Club, Absecon, N. J.

Oct. 18-20, National Assn. of Corrosion Engineers, south central region, Corpus Christi, Texas.

Oct. 19-20, Engineers' Council for Professional Development, annual meeting, Hotel Statler, Boston.

Oct. 22, AIME, Chicago Section, Open Hearth Committee, Phil Schmidt's, Chicago.

Oct. 22-24, American Mining Congress, Metal and Nonmetallic Mining Convention, Biltmore Hotel, Los Angeles.

Oct. 22-27, Societe Francaise de Metallurgie, congress, Paris, France.

Oct. 25-26, AIME, Los Angeles Section, fall meeting, Los Angeles.

Oct. 29-Nov. 3, AIME, fall meeting, Mexico City.

Oct. 30, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Nov. 2, AIME, Pittsburgh Local Section and Open Hearth Local Section annual off-the-record meeting. Wm. Penn Hotel, Pittsburgh.

Nov. 2, Illinois Mining Institute, annual meeting, Hotel Abraham Lincoln, Springfield, Ill.

Nov. 25-30, ASME, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Nov. 28-30, Scientific Apparatus Makers Assn., midyear meeting, laboratory apparatus, optical, nautical, aeronautical, and military instrument sections, Hotel New Yorker, New York.

Dec. 2-5, American Institute of Chemical Engineers, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Dec. 6-8, AIME, Electric Furnace Steel Conference, William Penn Hotel, Pittsburgh.

Dec. 11, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Jan. 16-18, 1952, Society of Plastic Engineers, Inc., annual national technical conference, Edgewater Beach Hotel, Chicago.

Feb. 18-21, AIME, annual meeting, Hotel Statler, New York.

Obituaries

Harry Hatch Burhans (Member 1937) has died. Mr. Burhans was born at Superior, Wis. in 1884 and attended Michigan College of Mines, Houghton, Mich., graduating in 1906 with the degree of E.M. Following graduation, several years were spent working in Mexico and Arizona. During World War I he was a First Lieutenant. In 1919 he joined the Yukon Mining Co., Yukon Territory, as superintendent. He later went to Colombia as mill superintendent for the Bar-Principal Mining Co. Mr. Burhans returned to New York in 1921 and was employed by the Dorr Co. Later he became associated with the Consolidated Mining Co. as operating engineer. In 1937 Mr. Burhans was manager, Varaguas Mines Ltd., Panama. He remained here for a short time and then joined R. T. Vanderbilt & Co., New York as field engineer. At the time of his death he was residing in Los Angeles.

Herbert B. Cox (Member 1904) died on Feb. 11 at the age of 91. Mr. Cox was born at Pittston, Maine on August 10, 1860. He received his engineering education at the Institute of Technology, Boston and Spring Garden Institute, Philadelphia. He joined the Charles River Iron Works, Cambridge, Mass. as a machinist apprentice and then became superintendent of the gas engine dept., Dickoon Mfg. Co., Scranton, Pa. Later he was made manager of the Scranton Passenger Railway Co. Mr. Cox joined the Lackawanna Iron & Steel Co., Scranton as master mechanic and assistant superintendent of blast furnaces. In 1904 he was appointed superintendent of the Cornwall and Lebanon furnaces with the same firm. He joined the Ringwood Co., New York in 1918 and later became associated with the Hewitt Realty Co. In 1921 he was appointed superintendent and metallurgical engineer for the same company. He moved to Winchester, Mass. and at the time of his death was residing there.

George C. Crossley

An Appreciation by Clyde W. Hall

George Corliss Crossley (Member 1917), president of the United Clay Mines Corp., Trenton, N. J., died as a result of an automobile accident on June 8, 1951. Mr. and Mrs. Crossley were proceeding westward bound from one of the company clay mines at Gleason, Tenn. when, due to rain and a winding road, control of their station wagon lapsed momentarily, resulting in a crash into a ditch, about eight miles from Chester, Ill. on June 7. Death came in the Chester hospital the following day. Mrs. Crossley escaped with minor injuries. He leaves behind a wife, Lou Sutphin Crossley, one daughter, one grandchild, one brother, one sister and quite a record of accomplishment, plus friends, high and low.

Mr. Crossley, George to most, was born of English stock in Trenton, N. J. on June 18, 1881. He attended local and private schools and later graduated from Drexel Institute, Philadelphia, with engineering as a background of preparation and training.

Early, young Crossley must have displayed an acumen for business on his own, because he was soon out on his own, rather than in with his father, a very substantial pottery machinery manufacturer of those days. He had what it takes—the knack of trade. Mining was it and from then on for the next 25 years he was never quite sure just how the next weekly payroll was going to be met. But it was. In 1905 what was later to become United Clay Mines Corp. was organized, under his corporate control then and continuously since. The beginning basis was pick-and shovel; growth was slow; hard; heartbreaking, almost. The turn came though, as it must for one so purposeful in mind and willing in body.

Clay-mining was Crossley's hobby; he lived it; he worked in it; he radiated the confidence so necessary in a young industry, which it was when he started. His presence therein was felt; people knew he was around. He lived to see quite some of his dreams come true; not all, but perhaps enough for one life. He was not much on outside interests, except his church. He did, however, head up the Prospect National Bank of Trenton from its organization many years ago; and he did allow enough time off to act as president of the Rotary Club in due time. Quite a traveler though, but ostensibly always on business, whether on the European Continent, or just to California.

George Crossley was a firm individual; not exactly fixed; somewhat unbending; resolute; plowing a straight furrow, if you please; almost permanent; aggressive, yes, but loyal; not of the "just-fade-away" type, even in later years, and than whom there was never a more rugged individualist of the old fashioned school. He seemed to have entered the world with a steadfast purpose already planted in his active mind. He aimed to do something; accomplish things. He did. That was George Crossley first, last, all the time.

Louis Clare Harrington (Member 1922), dean of the College of Engineering at the University of North Dakota, Grand Forks, died suddenly Feb. 3, 1951, at Pittsburgh, enroute home from Washington, D. C. Death was caused by an acute heart attack.

He was born in Ludington, Mich., Oct. 28, 1879. He obtained his secondary education in Ludington and then attended Michigan College of Mines at Houghton during the years 1901 to 1903. He spent the next several years 1903 to 1906 as a miner, assayer, and mining engineer at Bisbee, Ariz. He entered the University of Michigan and received his bachelor of science degree in civil engineering in 1908. Then he obtained the degree of mining engineer from Michigan College of Mines in 1909. He served as professor of geology and engineering at Western Maryland College during the years 1909-1912.

He came to the University of North Dakota in 1912 as instructor in mining and metallurgy. He served as assistant professor from 1913 to 1920, as associate professor from 1920 to 1921, and won his professorship in 1921. In 1931 he was appointed director of the div. of mines and mining experiments, and the next year dean of the College of Engineering. These positions he filled with conspicuous ability continuously until his death.

During the summers of 1913 to 1930 he was called upon to make mine examinations and valuations in Alaska, California, Kentucky, and North Dakota. Since 1938 he has been actively engaged as a consultant with the U. S. Bureau of Mines and he was active in research on the chemistry, combustion, drying, and gasification of lignite. His interest in lignite development and friendly cooperation with the U. S. Bureau of Mines influenced the Bureau to build two pilot plants on the campus and finally the Federal Lignite Laboratory, where they will conduct all of their research on the nation's lignite deposits.

Walter Hovey Hill (Member 1900), Legion of Honor member, died at Grangeville, Idaho at the age of 82. Mr. Hill had been overseeing some exploitation work on prospective zinc property when he was suddenly taken ill. He was born in Troy, N. Y., Oct. 3, 1868. He held a position as civil engineer with the A.T.&S. Railway. In 1889 he was employed on the waterworks construction job in Troy. He joined the C.&O. Railway 1890, and then went west to Boise as office engineer with the Idaho Mining & Irrigation Co. Soon after he entered private engineering practice.

He was also a surveyor-engineer for the Great Northern Railroad at the time its transcontinental line was being built. He was superintendent of the Buffalo Hump syndicate, Big Buffalo, Jumbo and Crackerjack properties. His mining knowledge assisted in the development of many mines in Idaho. He was also engaged in work on power plants and transmission lines. From 1920 to 1928 he was U. S. Mineral surveyor with an engineering practice in Boise. Later he served two terms as probate judge of Idaho County. In recent years he was consulting engineer for Rare Earths, Inc., of McCall.

John Kennedy (Member 1896) has died. Mr. Kennedy was born in 1862 at Melbourne, Victoria, Australia. He spent several years studying architecture and then practiced as a naval architect. In 1890 he took a course in mining at the Ballarat School of Mines and was then employed by the Broken Hill Mines, New South Wales as a miner and millman. In 1893 he was assistant-manager for the R. Kennedy & Sons Lead Smelting Works, Tasmania. He became ore purchasing agent in 1894 and in 1895 was made London agent for disposal of mine products. In 1896 he became a partner in the firm.

Karl F. Klein

An Appreciation by
James E. Harding

When Karl F. Klein died a good engineer went. In all his life he did high grade work but just as the great majority must do he was destined to live almost anonymously and die almost unknown except within the very limited circle in which he worked. Practically all his working life was spent in the South American countries, which combined with his excessively shy and retiring personality prevented his receiving even the local approbation which was his due.

Along about 1920 he was working with me at Potrerillos, Chile, when the Andes Copper Mining Co. was driving its long main haulage adit. The tunnel was 11,509 ft in length, all from one heading, with a curve at the inside end. From the final face of the tunnel, a raise was driven upward on a 45° slope for approximately 160 ft, then turned a 90° angle to the left and went up on a 60° slope to meet an incline shaft being sunk from surface. The connection was made with an error of 7.58 cm, which error was zero for all practical purposes and percentagewise far less than the error in closure in the Simplon tunnel in the Swiss Alps. For this quite extraordinary job of engineering Karl F. Klein was more responsible than anyone else. It was really extraordinary considering the fact that it was done with standard surveying equipment. The ventilation equipment of the tunnel was totally inadequate and at times more than 14,000 gal of water per min was flowing on the tunnel floor.

Then too, Karl was caught, just as hundreds of other young Americans were, by the first World War in South America without a passport, because up to that time many of us viewed the holder of a passport as something of a sissy and such documents were by no means necessary in general travel, least of all on a job.

Karl resigned his job and started for home to enlist. Then arose the passport difficulty. The necessary willing perjurors were found and the passport was procured. At Panama a vigilant official noticed the German name of Klein and worst of all the Karl with a K and that was that. It so happened that the writer of these lines was really well-known to a certain official of the Canal at that time, a cable was sent and Karl was sprung. By another even more remarkable coincidence, on his way to enlist, Karl arrived at Times Square just as the celebration started of the news that the European war was ended by the German surrender. His duty to his country done, a month later Karl was back on the job again and dead broke. Of course,

he had spent all his own money on the trip, both ways.

These few lines just to let the world know you were a very nice guy, Karl, and may your soul rest in peace.

James L. Leonard

An Appreciation by P. E. Oscarson

Late on May 5 the community of Spokane was shocked and saddened by the death of James L. Leonard, 42 year old mining engineer, from injuries sustained the previous day in an automobile accident.

James Leonard was born in Spokane, where he completed his secondary school education before going to Yale University for undergraduate work, and later to Cornell University for graduate work.

A member of a well-known mining family, he married Lou Miller of Brooklyn, N. Y., and returned to the Pacific Northwest to enter upon his career as a mining engineer by employment with the Pend Oreille Mines & Metals Co. at Metaline Falls, Wash. After a year at this location he moved to Spokane to participate in the affairs of Leonard, Matthews & Ryan, Inc., a mining, mortgage and real estate firm controlled by his family, and in the management of which he thereafter took an active part, and to establish close contact with the mining industry of the northwest. He continued an active interest in the Metaline district and adjacent northeastern Washington and southern British Columbia where he was a strong force in pushing development. At the time of his death he was president of Metaline Mining & Leasing Co. and director of Grandview Mines, producers in this area.

Because a back injury sustained on field work prevented him from joining the armed forces, he organized and directed a syndicate that put the Forest Rose Mine, a zinc-lead property in Montana, into production during the war.

Public affairs were a constant interest to him, having been Chairman of the Columbia Section, AIME; president of the Northwest Mining Assn.; president of the Associated Engineers of Spokane; member of Advisory Committee on Research, Washington State Planning Counsel; member of the Governor's Advisory Commission, State of Washington; member of Knights of Columbus, as well as several social clubs.

His activities were such that not only his family, but all of us will miss him.

Oscar Mamet (Member 1921) has died. Mr. Mamet was born at Bruges, Belgium on Feb. 4, 1874. He attended the University of Liege, Belgium from 1892 to 1897, where he specialized in science, physics, and mathematics and in 1897 was a civil mining engineer. After graduation he was employed as an engineer by Charbonnages de Kessales et Xhorrees in Belgium. He then joined the Societe John Cockerill, Seraing, Belgium. Mr. Mamet went to China as chief engineer for the Chinese Engineering & Mining Co. In 1919 he was employed by the Mines de Lincheng, China as engineering-manager. He was manager of the Mentoukou mines, Peking in 1921. He remained in China for several years and returned to Belgium in 1927. In 1933 he moved to Asserbrouck-Bruges, Belgium and was residing there at the time of his death.

William R. Maurer (Member 1947) died on Mar. 1 after a few days' illness. Born in Portsmouth, England on Aug. 9, 1906, he received the degree of B.Sc. in engineering from Cardiff University. He also attended the Technical School of Portsmouth and Winchester. Mr. Maurer was field engineer for Pirelli General, Southampton from 1929 to 1931. For four years he was employed by Edelenru Borsig, Magdeburg, Germany as erection engineer. He returned to England in 1937 to accept a position as research engineer for the National Oil Refineries. In 1940 he became superintendent for E. Curran Nonferrous Melting & Rolling. Mr. Maurer went to India in 1943 as works manager, production, in the Indian Ordnance Service. In 1946 he was made superintending engineer for Birla Bros., India. He remained in India for several years, returning to England in 1949. In 1950 he joined the English Steel Corp., Ltd., Vickers Works, Sheffield as technical representative.

Robert H. Ogburn (Member 1921) died on Mar. 1, 1951 after a long illness. He had retired last August as assistant general manager in charge of Fairbanks operations of U. S. Smelting, Refining & Mining Co. after 25 years with the company. Mr. Ogburn was born in 1885 at Angus, Ontario and attended Vashon Academy, Burton, Wash. For several years he prospected in the Yukon Territory and then entered the employ of the Yukon Gold Co. In 1925 he was employed as a construction man by the Fairbanks Exploration Co. He held successively the position of surveyor, thawing and stripping superintendent, assistant manager and in 1946 became assistant general manager. At the time of his death he was residing in Mesa, Ariz.

Joseph Pursglove, Sr. (Member 1944), formerly one of the leading producers in the bituminous coal fields of West Virginia and Ohio, died Apr. 24. Mr. Pursglove was born in Ripley, England, but came to Connellsville, Pa. in 1882. At the age of 14 he worked as a trapper boy in the Pennsylvania mines where he learned the coal business. He and three brothers began their own business as coal producers at the turn of the century. He was president of the firm known as the Pursglove Coal Mining Co., Pursglove, W. Va. They operated mines in Logan, Harrison, and Monongalia counties in West Virginia, and Belmont county in Ohio. In 1943 the company was sold to Pittsburgh Consolidation Coal Co. In recent years, Mr. Pursglove was a well-known coal distributor in Cleveland.

Frederick Fraley Sharpless (Member 1889), a former Secretary of AIME, died on Apr. 11. Mr. Sharpless, born in West Chester, Pa. in 1866, attended the state normal school in that town, completing his education at the University of Michigan. He graduated in 1888 with the degree of B.S. in chemistry. Following graduation he was an instructor in metallurgical chemistry, assaying and ore dressing at the Michigan School of Mines, Houghton. In 1893 he opened a chemical laboratory in Minneapolis and examined and reported on iron mines and precious metal mines in the Northwest. He later became a consulting engineer for the Consolidated Mines Selection Co. Ltd. of London. While associated with this firm he traveled through North America, Mexico, Central and South America, West Africa, and Turkey. From 1912 to 1921 he maintained a consulting office in New York. Mr. Sharpless became Secretary of AIME in 1921. He returned to his practice in 1925 and retired in 1938.

Raymond Edgar Tower (Member 1945) has died. Born in Missoula, Mont. on Feb. 24, 1889, he attended Montana School of Mines at Butte. He was manager, Tower & Templeman Leasing Co. from 1915 to 1919. During this same time he was superintendent, St. Louis Mining & Milling Co., Marysville, Mont. He joined the Silver Fissure Mining Co. in 1919 and in 1925 went to Kamloops, B. C. as mill superintendent for the Iron Mask Mining Co. For several years Mr. Tower did general consulting work in Mexico. He became manager for the Gold Coin Mining Co., Pittsburgh in 1931 and in 1941 was engaged in private practice and operation of the Hidden Lake, Mont. mine. During World War II he served as chief chemist for the metals reserve plant at Columbus, Mont. At the time of his death he was vice-president and manager of the Sarita Milling Co., Salt Lake City.

NECROLOGY

Date Elected	Name	Date of Death
1889	George H. Ashley	May 28, 1951
1936	Cecil E. Bales	May 26, 1951
1936	Walter M. Charman	June 15, 1951
1904	Herbert B. Cox	Feb. 11, 1951
1917	George C. Crossley	June 8, 1951
1883	F. Lynwood Garrison	June 10, 1951
1944	Kenneth V. Haig	Mar. 27, 1951
1900	Walter Hovey Hill	June 10, 1951
1921	Oscar Mamet	Unknown
1947	William R. Maurer	Mar. 1, 1951
1928	Howard Palmer	Unknown
1928	Eugene P. Shove	Unknown
1928	William R. Tonkin	Unknown

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on June 30, 1951 was 17,282; in addition 2,498 Student Associates were enrolled.

ADMISSIONS COMMITTEE

Thomas G. Moore, Chairman; Carroll A. Garner, Vice-Chairman; George B. Corless. F. W. Hanson, Albert J. Phillips, Lloyd C. Gibson, R. D. Mollison, John T. Sherman. Alternates: A. C. Brinker, H. W. Hitzrot, Plato Malozemoff, Ivan Given, T. D. Jones, and W. H. Farrand.

Institute members are urged to review this list as soon as the issue is received and immediately write the Secretary's Office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified. Objections must be received before the 30th of the month on Metals and Mining Branches.

In the following list C/S means change of status; R, reinstatement; M, Member; J. Junior Member; A, Associate Member; S, Student Associate.

Arizona
Naco—Ashe, Donald G. (J) (R. C/S—S-J)

California
Berkeley—Stewart, Thomas A. (J) (C/S—S-J)
Berkeley—Zerda, Kenneth V. (J) (C/S—S-J)
Los Angeles—Adler, Lawrence (J) (R. C/S—S-J)
Madera—Jones, John K. (J) (C/S—S-J)
Riverside—Weeks, LeRoy W. (A)
Trona—Vujnovich, Mike (J) (R. C/S—S-J)
Vallajo—Ahrens, Ernst H., Jr. (J) (C/S—S-J)

B. B. R. DRILLING CO.
Scenery Hill   Martins Ferry, O.
Diamond Core Drilling Contractors
Mineral Cores Guaranteed   Foundation Testing

CIA. DE PERFURACOES COMERCIAIS S.A.
Drillings, Examinations, Reports, and Consulting of Mineral Deposits. Manganese, Chrome, Copper, Graphite, Lead, Tungsten, Asbestos, Bauxite, Tin, Diamonds, Gold, Mica, Quartz Crystals, Lithium, Vanadium, Coal, etc., deposits to be developed.
Caixa Postal, 5428, Rio de Janeiro, Brazil
Cable Drillersbrazil—Rio

EAVENSON & AUCHMUTY
MINING ENGINEERS
Mine Operation Consultants
Coal Property Valuations
2720 Koppers Bldg.   Pittsburgh 19, Pa.

CHESTER A. FULTON
Consulting Mining Engineer
10 East 40 St.   New York City 16
MUrray Hill 9-1530
302 Somerset Rd.   Baltimore 10, Md.
Belmont 1353

T. W. GUY
Consulting Engineer
Coal Preparation
To Yield Maximum Net Return
Face and Product Studies
Plant Design and Operation
Kanawha V. Bldg.   Charleston, W. Va.

ABBOT A. HANKS, Inc.
ASSAYERS-CHEMISTS
Shippers Representatives
624 Sacramento Street
SAN FRANCISCO

DIAMOND CORE DRILLING BY CONTRACT
and world's largest manufacturer
Core and grout hole drilling in coal, metal, and non-metallic deposits, both surface and underground.
JOY MANUFACTURING CO.
Contract Core Drill Division
Michigan City, Indiana

E. J. LONGYEAR COMPANY
Foshay Tower   Minneapolis, Minn.
Consulting Mining Engineers and Geologists
Mineral Exploration   Mine Valuation

DIAMOND CORE DRILLING CONTRACTORS
Testing Mineral Deposits
Foundation Borings
MOTT CORE DRILLING CO.
Huntington, W. Va.

PENNSYLVANIA DRILLING COMPANY
PITTSBURGH 20, PA.
DRILLING CONTRACTORS and MANUFACTURERS
We prospect coal and mineral land anywhere in North and South America.
Core borings for foundation testing; dams, bridges, buildings, etc.

PIERCE MANAGEMENT, INC.
MINING ENGINEERS
A Background of 22 Years of Design, Consulting, and Management Service to Coal and Mineral Industries in 28 States and 18 Foreign Countries.
Scranton Electric Bldg. Scranton 3, Pa.
1025 Connecticut Ave., N.W.
Washington 6, D. C.

ROGER V. PIERCE
Mining Engineer Specialist
Underground Mining Methods, Cost Cutting Surveys—Production Analysis—Mine Mechanization—Mine Management.
808 Newhouse Bldg.   Phone 33973
Salt Lake City 4, Utah

SPRAGUE & HENWOOD, Inc.
SCRANTON 2, PA.
Diamond Drill Contractors and Manufacturers
Core borings for testing mineral deposits in any part of the world.

CARL G. STIFEL REALTY CO.
For Industrial Plants, or Plant Sites, of any size . . . anywhere in the United States or Canada, write, phone or wire
CARL G. STIFEL
224 N. 4th St.   St. Louis, Mo.
Central 4810

UNDERPINNING & FOUNDATION COMPANY, INC.
155 EAST 44TH STREET
NEW YORK 17, N. Y.
Specialists in Design and Construction of Shafts and Tunnels

G. A. VISSAC
Consulting Engineer
COAL DRYING
Vancouver Block   Vancouver, B.C.

S. POWER (Pi) WARREN, EM.MSc.
MINERAL AND METAL BENEFICIATION PROBLEMS
Only those commitments desired which include personal, on the job attention
1910 Kalorama Rd., N.W.   North 3442
WASHINGTON 9, D. C.

W. T. WARREN
V.P., MacLean Development Corp.
Mining Engineer—Consultant
1. Examinations & General Analysis
2. Underground Operating Problems
a) Safety   c) Secondary Blasting
b) Low-cost Stoping   d) Production
MacLean Development Corporation
Route 1, Box 440   Reno, Nevada

JOEL H. WATKINS
Mining Geologist
INDUSTRIAL MINERALS
CHARLOTTE C. H.   VIRGINIA

WEISS GEOPHYSICAL CORPORATION
Mining geophysical surveys with aerial and ground magnetic, gravimetric, seismic and electrical methods; research and development. Experienced crews for systematic work in any part of the world.
149 Broadway   REctor 2-6294
New York 6, N. Y. Cable: "Geophysics"

The Original
ALLEN GROU-TROL PROCESS
Division
WELL SERVICE INC.
Experienced and engineered
pressure grouting service
Sub-surface water control.
Dick Allen, General Manager
19th Fl., Kanawha Valley Bldg.
Charleston 1   West Virginia

J. W. WOOMER & ASSOCIATES
Consulting Mining Engineers
Modern Mining Systems and Designs
Foreign and Domestic Mining Reports
Union Trust Bldg., Pittsburgh, Pa.
National Bank Bldg., Wheeling, W. Va.

L. E. YOUNG
Consulting Engineer
Mine Mechanization — Mine Management
Oliver Building   Pittsburgh, Pa.

Colorado
Gilman—Bullock, Richard L. (J) (C/S—S-J)
Uravan—Paris, Everett M. (M) (C/S—A-M)

District of Columbia
Washington—Alt, Jacob W. (M)
Washington—Sengupta, Kulabhusan (M)

Idaho
Stibnite—Winterhalder, Erwin C. (J) (C/S—S-J)
Wallace—Sather, Norman J. (M) (C/S—A-M)

Illinois
Berwyn—Garyotis, Walter B. (J)
Park Ridge—Larsen, Edward P. (M)
Urbana—Bevan, Arthur C. (M) (R.)

Kentucky
Benham—Irwin, Clyde H. (M)
Pikeville—Mosgrove, J. H. (M)
Price—Greer, Robert D. (M)
Wheelwright—McClure, Thomas V. (J)

Massachusetts
Wollaston—Zucker, Gordon L. (J) (C/S—S-J)

Michigan
Calumet—Gedge, George (M)

Minnesota
Duluth—Forciea, James E. (J) (R. (C/S—S-J)
Duluth—Phillips, Chelsea R. (M) (C/S—A-M)
Hibbing—Watson, William W. (M) (R.)
Marble—Hayden, George S. (J)
Minneapolis—Davis, Robert B. (J) (C/S—S-J)
Minneapolis—Elliott, James (M)
Minneapolis—Lindquist, Einer D. (J) (R. C/S—S-J)
Minneapolis—MacLennan, John R. (J) (C/S—S-J)
Mountain Iron—Suihkonen, John A. (J) (C/S—S-J)
Nashwauk—Dicks, Sheldon J. (J) (C/S—S-J)
St. Cloud—Sersen, Thomas C. (J)
Sleepy Eye—Connor, Arnold G. (J) (R. C/S—S-J)
Underwood—Bergem, George P. (J) (C/S—S-J)
Willmar—Pearson, William P. (J)

Missouri
Joplin—Jones, Philip L. (M)

Nebraska
Ashland—Reim, Kenneth M. (J) (C/S—S-J)

Nevada
Empire—Wood, William B. (A) (C/S—S-A)

New York
Katonah—Harris, Stuart I. (J) (C/S—S-J)
Newburgh—McEvilly, William G. (J) (R. C/S—S-J)
New York—Rooney, Fred S. (M)

Ohio
Warrensville Heights—Hassett, John S. (J)

Oregon
Portland—Brooke, Robert E. (M) (R. C/S—J-M)

Pennsylvania
Erie—Scheffer, Earl (J) (C/S—S-J)
Indiana—Kain, Arthur F. (M)
Philadelphia—Donnelly, Joseph B. (M)
Pittsburgh—Parse, Richard G. (M)

Utah
Marysvale—Caywood, Roger M. (J) (C/S—S-J)

Virginia
Norton—Benson, James B. (M)
Norton—Malesky, Joseph S. (M) (R. C/S—J-M)

West Virginia
Charleston—Briney, William F. (A)
Powellton—Leighton, Joseph C. (J)

Wisconsin
Benton—Farrey, Henry B. (A) (R. C/S—S-J)

Canada
Ontario—Seeber, Orville A. (M)

South America
Colombia—Newns, Donald W. (M)

Iran
Teheran—Zahedi, Ali (M)

Mexico
Mexico City—Terrones Langone, Eduardo (A)
Oaxaca—Hamilton, Harloe H. (A)

Peru
Arequipa—Coakley, Patrick D. (J)

Advertisers' Index

Allen-Sherman-Hoff Pump Co. ..... Third Cover
Dee Carlton Brown, Advertising

Allis-Chalmers Mfg. Co. 637, 649
Compton Advertising, Inc.

American Cyanamid Co. 648B, 648C
James J. McMahon, Inc.

American Manganese Steel Div., American Brake Shoe Co. ..... *
Fuller & Smith & Ross, Inc.

Anaconda Copper Mining Co. 634
Kenyon & Eckhardt Inc.

Boeing Airplane Co. 653
N. W. Ayer & Son

Carlon Products Corp. 648D
Penn and Hamaker, Inc.

Clarkson Mfg. Co. ..... *
Batz-Hodgson-Neuwoehner

Climax Molybdenum Co. 648A
Rowlinson-Broughton

Colorado Fuel & Iron Corp. ..... *
The Shaw-Schump Adv. Agency, Inc.

Colorado Fuel & Iron Corp. Wickwire Spencer Steel Div. ..... *
Doyle, Kitchen & McCormick, Inc.

Deister Concentrator Co. 733
Louis B. Wade, Inc.

Denver Equipment Co. 662

Dings Magnetic Separator 638
Russell T. Gray, Inc.

Dorr Co., The 636

Dow Chemical Co., The ..... *
MacManus, John & Adams, Inc.

Eimco Corp., The 635
Matsie Co.

Flexible Steel Lacing Co. ..... *
Kreicker & Meloan, Inc.

Flexible Tubing Corp. ..... *
McNevin, Wilson, Dalldorf, Inc.

Gardner-Denver Co. 643
The Buchen Co.

General Electric Co. 644, 645
G. M. Basford Co.

Hardinge Co., Inc. 727
The W. H. Long Co.

Hendrick Mfg. Co. ..... *
G. M. Basford Co.

Hercules Powder Co. (Explosives) 657
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) ..... *
Fuller & Smith & Ross, Inc.

Heyl & Patterson, Inc. 640
Dan A. Sullivan Adv.

Ingersoll-Rand Co. 656
Rickard & Co.

International Nickel Co., Inc. 660
Marschalk & Pratt Co.

Joy Mfg. Co. ..... *
Walker & Downing

Le Roi Co. 641
Hoffman & York, Inc.

Longyear Co., E. J. 726
F. H. Faber Adv.

Lubriplate Div., Fiske Bros. Refining Co. 647
E. M. Freystadt Assoc.

Mine & Smelter Supply Co. 732
The Shaw-Schump Adv. Agency, Inc.

Mine Safety Appliances Co. ..... Fourth Cover
Ketchum, MacLeod & Grove, Inc.

Morse Bros. Machinery Co. 648
Max Goldberg Adv. Agency

Nordberg Mfg. Co. 646
Russell T. Gray, Inc.

Sauerman Bros., Inc. 728
Symonds, MacKenzie & Co.

Sheffield Steel Co. ..... *
R. J. Potts-Calkins & Holden Adv.

Smit & Co., Inc., Anton 647
Laughlin-Wilson-Baxter & Persons

Smit & Sons, Inc., J. K. 651
Mercready, Handy & Van Denburgh

Sprague & Henwood, Inc. ..... *
Frederick B. Garrahan Adv.

Stearns Magnetic Mfg. Co. 652
Eldred Vetter Agency

Stearns-Roger Mfg. Co. 729
Gray & Co., Inc.

Texas Gulf Sulphur Co. 650
Sanger-Funnell, Inc.

Traylor Engineering & Mfg. Co. 639
Kamp and Godfrey, Inc.

Tyler Co., W. S. 642

Sugarman Co., J. J. 728
The Mayers Co., Inc.

Western Machinery Co. ..... *
Walther-Boland Associates

Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp. ..... *
Doyle, Kitchen & McCormick, Inc.

Wilfley & Sons, Inc., A. R. ..... Second Cover
Ed M. Hunter & Co.

Wilmot Engineering Co. ..... *
Wilbur A. Myers Adv.

Yuba Mfg. Co. 730
Geo. C. McNutt Adv.